PICTURE REGENERATION FROM QUANTIZED DATA

A THESIS

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Science

by

Juris George Raudseps, B.S.E.

The Ohio State University
1963

Approved by

F. C. Weimer
Adviser
Department of Electrical
Engineering

CONTENTS

CHAPTER I
INTRODUCTION

An exact description of an ordinary black-and-white, half-tone image can be given only by specifying the exact shade of gray to be found at every mathematical point of the image. The most complete description that can be given in digital form consists of a table of average shades of gray, specified only with some finite precision, and given for every one of a set of finite sections of the image. Conceptually, such a digital description can be made arbitrarily close to the exact description by making both the increments between successive discrete shades of gray and the increments of area sufficiently small. Practically, such a description is not particularly desirable because it requires an enormous amount of hardware for analysis and storage.

Any normal image will contain definite contours, indicating physical boundaries of some type in the object represented, and areas of uniform or gradually varying shades. Within some areas the shades of gray at any point can be predicted fairly precisely from a knowledge of the shades of gray at other points in its neighborhood. A specification of the shades of gray at that point is therefore to some degree redundant. In devising a practical system to describe the image, one would seek efficiency by eliminating as

much redundancy as possible from the description. In the absence of any clearly defined measure of information content of a picture, the test of any scheme to minimize the data that need to be recorded to preserve the essential content of the picture is whether the picture can be reconstructed in original form with the data given.

One possible method of describing a picture economically is to specify a set of constant-intensity contours drawn for relatively few shades of gray distributed through the range of shades encountered. Describing a picture by its constant-intensity contours is equivalent in every way to drawing it in discrete or quantized levels of gray, showing all shades in the continuum between any two adjacent discrete levels as one of these. A similar equivalence exists between a map in which elevation is indicated by contours of constant altitude (isometric lines) and one in which it is shown by coloring regions in certain ranges of altitude in various shades of brown and green. The boundaries between adjacent colors are isometric lines.

W. F. Haagen has investigated several methods of constructing efficient codes for transmitting a picture reduced to its constant-intensity contours and has computed approximate values of the channel capacities required to transmit a picture in each code.[1] His work indicates that very substantial reductions in the required channel capacity (on the order of one to one hundred) can be

achieved by these methods. His justification for assuming that constant-intensity contours form an adequate description of a picture is founded on the physiological properties of the human eye.

This report describes a direct investigation of the adequacy of the constant-level-contour description of a picture. It is, of course, clear that information is destroyed in the process of contour extraction, as it would be in any data-reduction process that produced less than an exact description of the original picture. If, however, a way can be found to restore from the contours a picture that for the purpose in question is not materially different from the original, we can ignore the information loss as insignificant. Various measures of error have been defined which could be used to test the fit between the original and the reconstructed versions of a picture. It is, however, doubtful whether any mathematical test would be as useful as the most direct check of the similarity- visual inspection. The investigation was therefore confined to an attempt to reconstruct from a quantized picture a picture which to the human eye would appear as an acceptable representation of the object shown - a woman's head in profile. While different characteristics of a given picture may be important in different applications, it seems fairly safe to assume that visual inspection of the reconstructed image will reveal most of its defects that might be significant.

CHAPTER II
METHOD

The principal device used for the picture regeneration was an IBM-1620 digital computer. A picture for testing purposes was handpainted in quantized form. The grid coordinates of the equal-intensity contours were punched into cards and fed into the computer, which performed the smoothing operation. The computer output was in the form of paper tape, which, after a change of format, was used to activate a special automatic typewriter capable of typing small squares in various shades of gray. As a final step, the picture that had been typed was photographed slightly out of focus to reduce grain.

The test picture (Fig. 1) was painted in six distinct shades, ranging from black to a very light gray subsequently assumed to be white. It was based partly on a photograph from a magazine, partly (principally in the hair region) on the artist's imagination. The six discrete intensity levels were assumed to be uniformly spaced. The quantizing was done by eye, and the accuracy of the quantizing may therefore be open to question in some instances. On the whole, however, the test picture appears adequate for the needs of this study.

Fig. 1. Picture after quantizing by artist.

To obtain input data for the computer, an acetate grid was superimposed on the picture and the picture was scanned line by line. At each intersection of the scanning line with a boundary, the horizontal (x) coordinate of the intersection and the number representing the following shade were recorded. For the 14" x 12" picture with a grid ruled 40 lines to the inch, this scanning resulted in some ten thousand input points. The data were punched into cards. For checking purposes, the computer was programmed to produce output tape that resulted in the picture being typed in quantized form (Fig. 2). The errors in the data could be readily seen as flaws in the picture and were corrected before further work was done.

Two different computer programs were written and used to smooth the picture. Numerical values were assigned to the shades in the picture, ranging from 0 for black to 500 for white. The values of intensity at the input points were assumed known and fixed. For all other grid points, numerical values for the intensity were calculated. These values were encoded as appropriate symbols and punched into the output tape.

Ideally, the shade typed in any grid square should have been the exact shade calculated for that point, or at least one sufficiently close to be indistinguishable to the human eye. No device capable of producing the required number of discrete shades (approximately

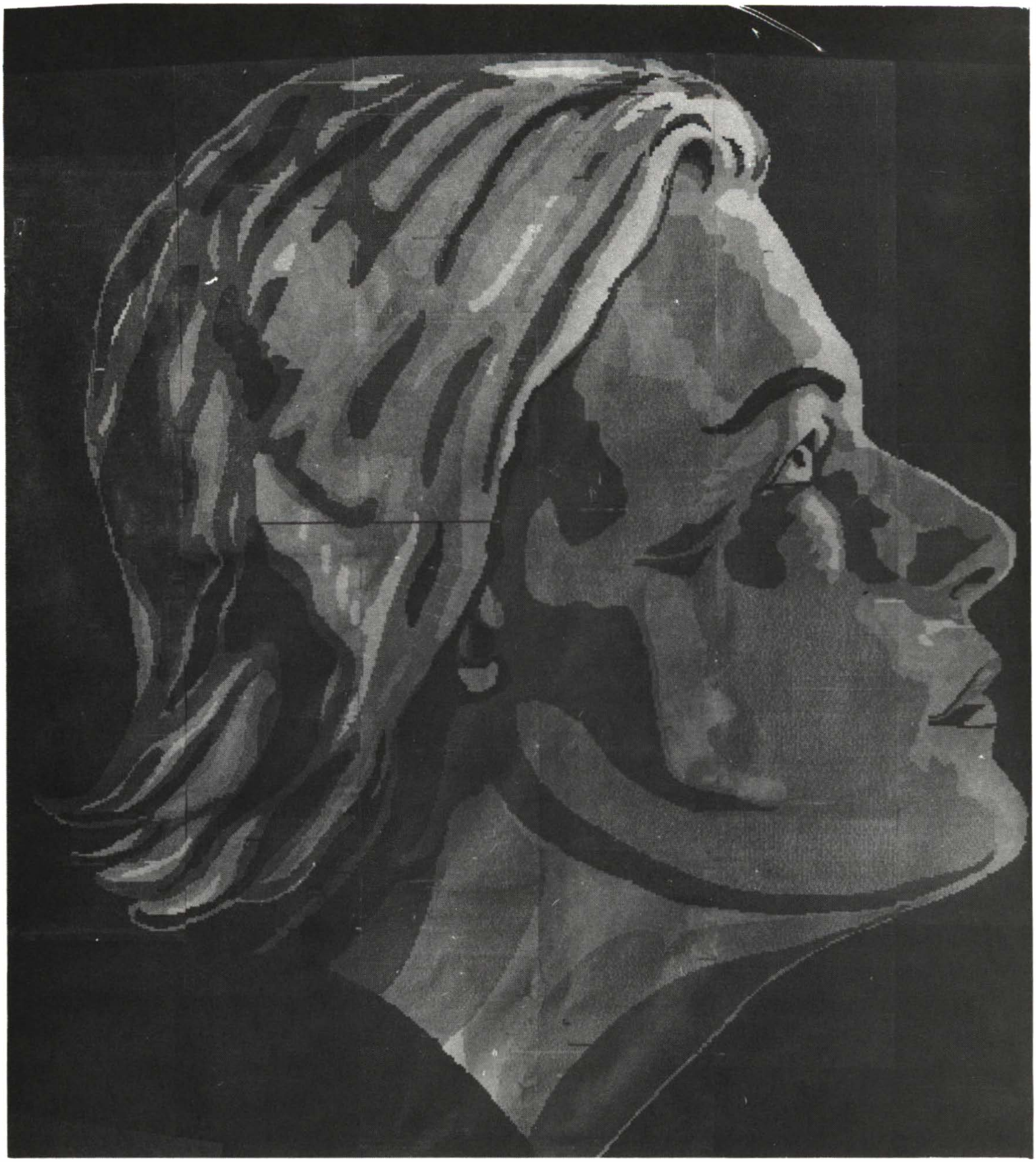
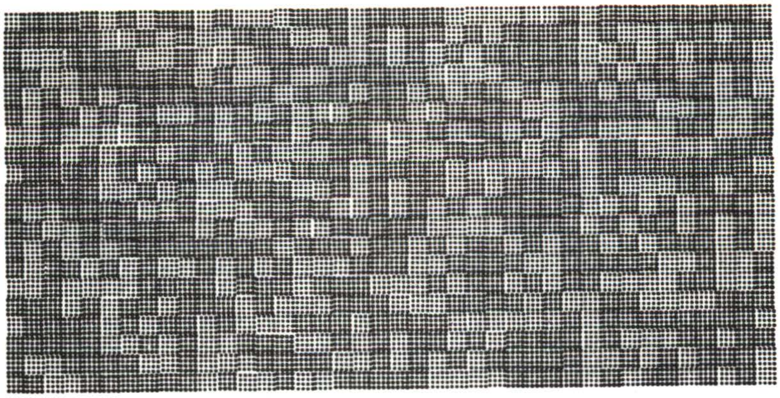
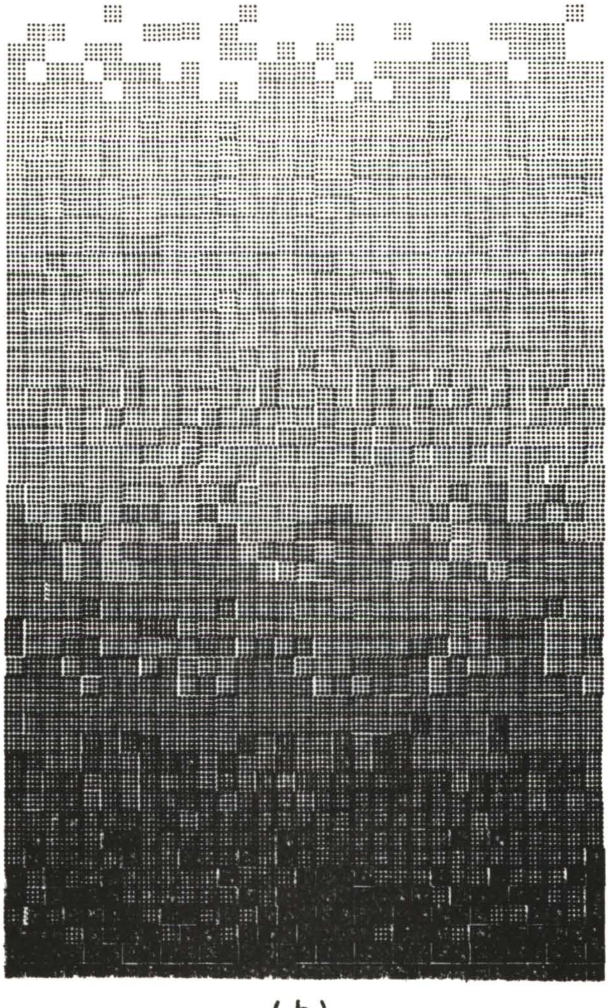


Fig. 2. Quantized picture produced from scan data for checking purposes.

64, depending on ambient light conditions) was available. The modified "Flexowriter" used could produce only nine shades, ranging from black to white. To schieve the effect of continuously varying shades, the nine available shades were mixed in proper proportions to give the intermediate shade desired. For instance, if the shade desired in an output square corresponded to 430, while the nearest shades available on the typewriter corresponded to 400 and 500, one of these was picked at random, the probabilities having been adjusted to 0.7 for the 400 shade and 0.3 for the 500 shade. It was assumed that the available shades were spaced uniformly. This assumption, unfortunately, was not valid, as can be seen from Fig. 3 in which a gray scale is shown, constructed by letting the numerical equivalent of the shade vary linearly from 0 to 500 at intervals of ten. The figure reveals two types of difficulties: the contrast between pure white and the lightest shade of gray is too abrupt, and the contrast between every pair of adjacent gray levels is not the same.



(a)



(b)

Fig. 3. a) Random mixture of two adjacent shades produced by output Flexowriter. b) Continuous gray scale produced by output Flexowriter.

CHAPTER III
REGENERATION SCHEME I

The mathematical function used to compute the shade in each grid square was chosen on the basis that it satisfied a number of requirements for a smoothing scheme. Since the function was to be generated by digital computer, no particular consideration was given to the question whether the function could be conveniently generated by circuits capable of operating at rates commensurate with ordinary television, for instance. This scheme sould therefore be considered as being analogous to a mathematical existence proof for a solution, not a computational method for finding the solution.

The requirements placed upon the output picture were basically that it retain the constant-intensity contours of the quantized version, these being its only direct link with the original; and that it be reasonably free from distortion objectionable to the eye. It is known that the eye is relatively far more sensitive to sudden transitions in light intensity than it is to absolute intensity levels. This fact dictated the requirement that the step transitions in the quantized picture that did not correspond to any actual physical boundaries of the object represented be made into smooth transitions. Furthermore, a sharp change in the rate of change of shade (the space derivative) was also considered undesirable, since the eye would probably be

unduly sensitive to that as well. At the same time, shade transitions in the picture due to real physical boundaries had to be maintained reasonably sharp.

The combination of these requirements — preservation of known constant-intensity contours, smoothing of step changes due to slow variation, and preservation of sharp step transitions — dictated that the function employed be of a curve-fitting nature, rather than some kind of weighted average of surrounding known points. For relative simplicity in programming, it was decided to fit smooth curves between the known points along each scanning line.

Several well-known curve-fitting schemes exist for approximating values of tabulated functions at points not given in the table. These schemes all employ the principle of fitting polynomials through a set of adjacent points. In general, it is assumed that polynomials of higher order will give a better fit to the function being approximated. It was found that these schemes were not applicable to the situation considered here. The simplest — ordinary linear interpolation — in general causes a nonpermissible discontinuity in the derivative at each input point. Ordinary parabolas could not be used because they would introduce unjustifiable asymmetry. A parabola is determined by three known points. The value of the smoothing function calculated at a given point on the basis of two

fixed points to its left and one on its right would in general differ from that calculated on the basis of two fixed points on its right and one on its left. Similar considerations would rule out the use of any even polynomials of higher order. An attempt to use a cubic parabola as a smoothing function revealed that it, too, was unsuitable, giving violent overshoots, often far out of the range of possible values. This instability was particularly noticeable and objectionable in cases such as that shown in Fig. 4, where the shape of the curve in relative long spans was largely determined by the pairs of closely spaced points on the ends. Attempts to use polynomials of higher

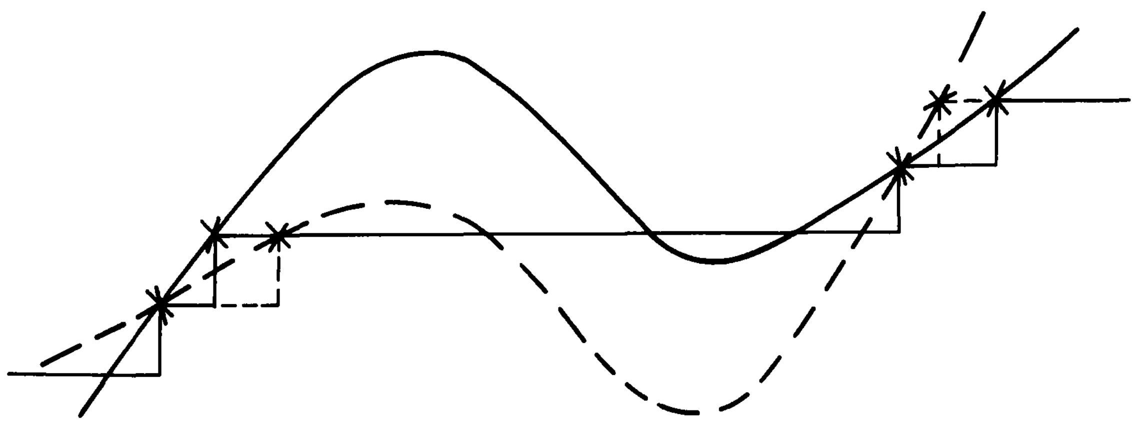


Fig. 4. Dependence of cubic parabola on slight displacement of the fixed points through which it is fitted.

order could be expected to lead to even worse behavior. In addition, none of the ordinary polynomial fitting schemes will in general give a continuous derivative at the transitions from a span computed on the basis of one set of points to one computed from another set.

A special curve-fitting scheme was therefore devised which introduced no asymmetry, preserved continuity of derivatives at the fixed points, and minimized the problem of overshoots (Fig. 5). The scheme was the following: A parabola was computed passing through every set of three adjacent fixed points. This resulted in two parabolas, generally different, associated with all but the two extreme spans between fixed points. The value of the output function was assumed to be the weighted sum of these parabolas, given by the expression

$$f(x) = p_{-}(x) \frac{x_1 - x}{x_1 - x_{-1}} + p_{+}(x) \frac{x - x_{-1}}{x_1 - x_{-1}} \quad .$$

Thus each parabola segment was given a weight that was unity at the middle one of the three points determining it, and decreased linearly to zero at each outer point. The resulting function clearly has a continuous derivative at each fixed point equal in value to that of the parabola centered at that point.

Since the parabolas could still overshoot in such a manner as to make the regenerated function assume values not compatible with the limits on the function indicated by the quantizing, the parabolas were clipped previously to the weighted averaging, as illustrated in Fig. 6. The clipping levels were chosen one quantizing increment above and below the quantized level of the span.

The clipping clearly introduced discontinuities in the derivative at the points of transition from a parabola to a straight horizontal line. Because of the nature of the weighting function, one of these discontinuities was made negligibly small in the final smoothing function. The other was considered acceptable since it could occur only near transitions from a short span with sharply changing shade to a fairly long and rather uniform span between fixed points. Such a transition was assumed to represent a boundary in the object shown and therefore to be a real discontinuity.

Exceptions necessarily had to be made to this general rule for computing the regenerating function for several cases where it could not be applied. The black background of the picture was always shown black. The two spans on the extreme right and left of each scanning line had only one parabola segment associated with them (rather than two, as for the interior spans), and this was used as the regenerating function in those spans. If only one shade was encountered in

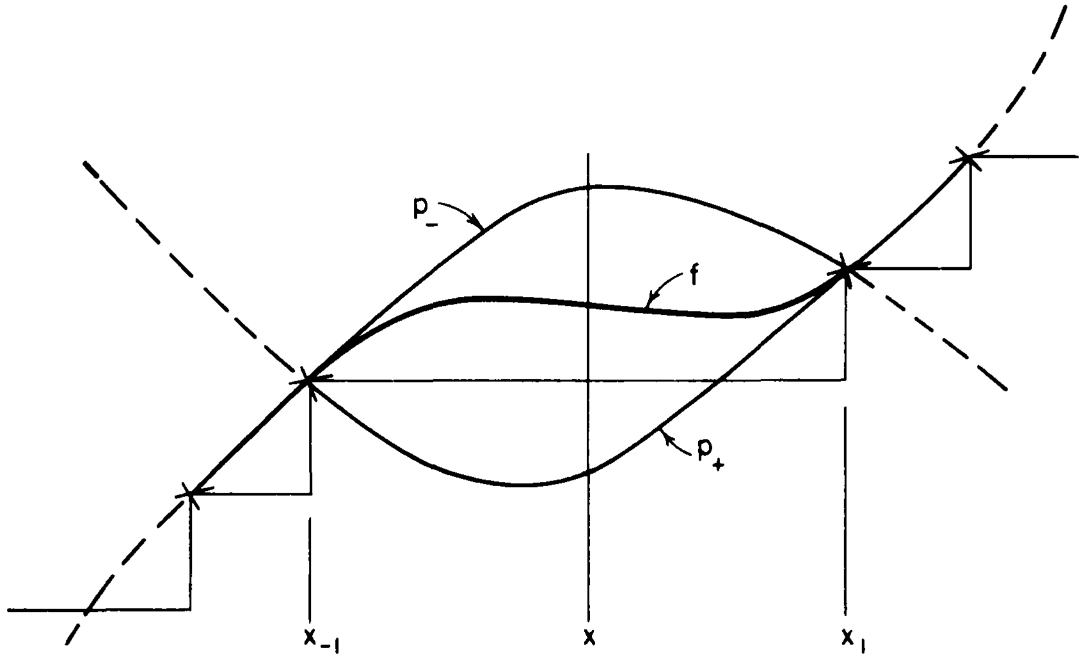


Fig. 5. Fitting weighted average of parabolas to fixed points.

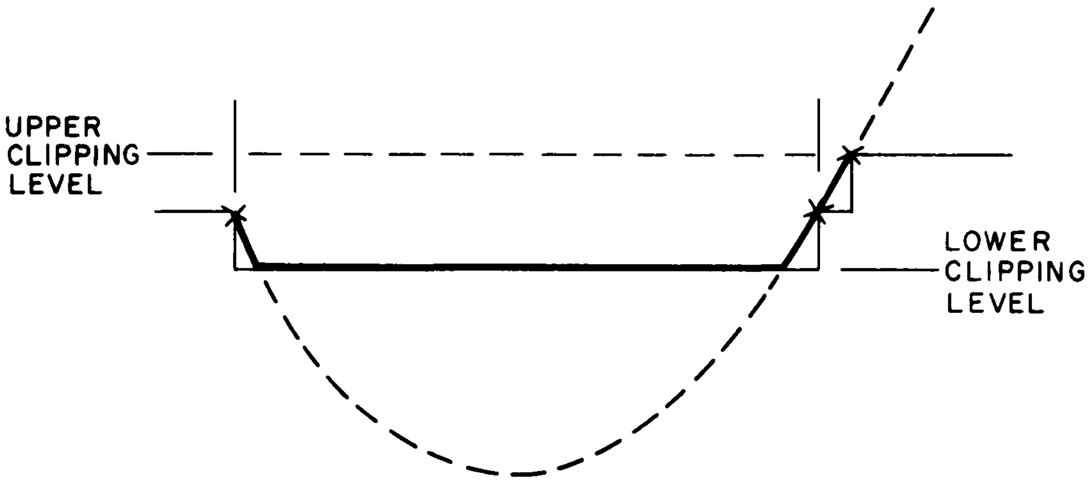


Fig. 6. Clipping of parabola.

scanning across the quantized picture at a given level, it was used in the regenerated picture as well, there being not enough points to fit a parabola.

The correspondence of the fixed points used in fitting the curve to the input data can be seen in Fig. 7. As should be noted, it was assumed that no complete discontinuities in shade occured such that several constant-intensity lines could coincide (in terms of the analogy with maps, there could be no perfectly vertical cliff walls). Where the input data indicated transitions across several quantizing levels, these were considered to be caused by insufficient resolution by the quantizer and were broken down into a series of single-step transitions. Such breaking down was necessary to make valid the curve-fitting scheme described.

The flow diagram for the computer program to produce the regenerated picture is shown in Fig. 8. Since the output picture was far too wide to be typed at one pass (48 inches, each unit being 1/10 inch square), it was computed and typed in vertical strips. The input data-card deck was fed through the computer for each strip, and on each pass the program set the fixed points and performed the computations only for the proper part of every line. No discontinuity in the output function along any line was created by its piecewise calculation, and the adjacent strips of the picture joined smoothly.

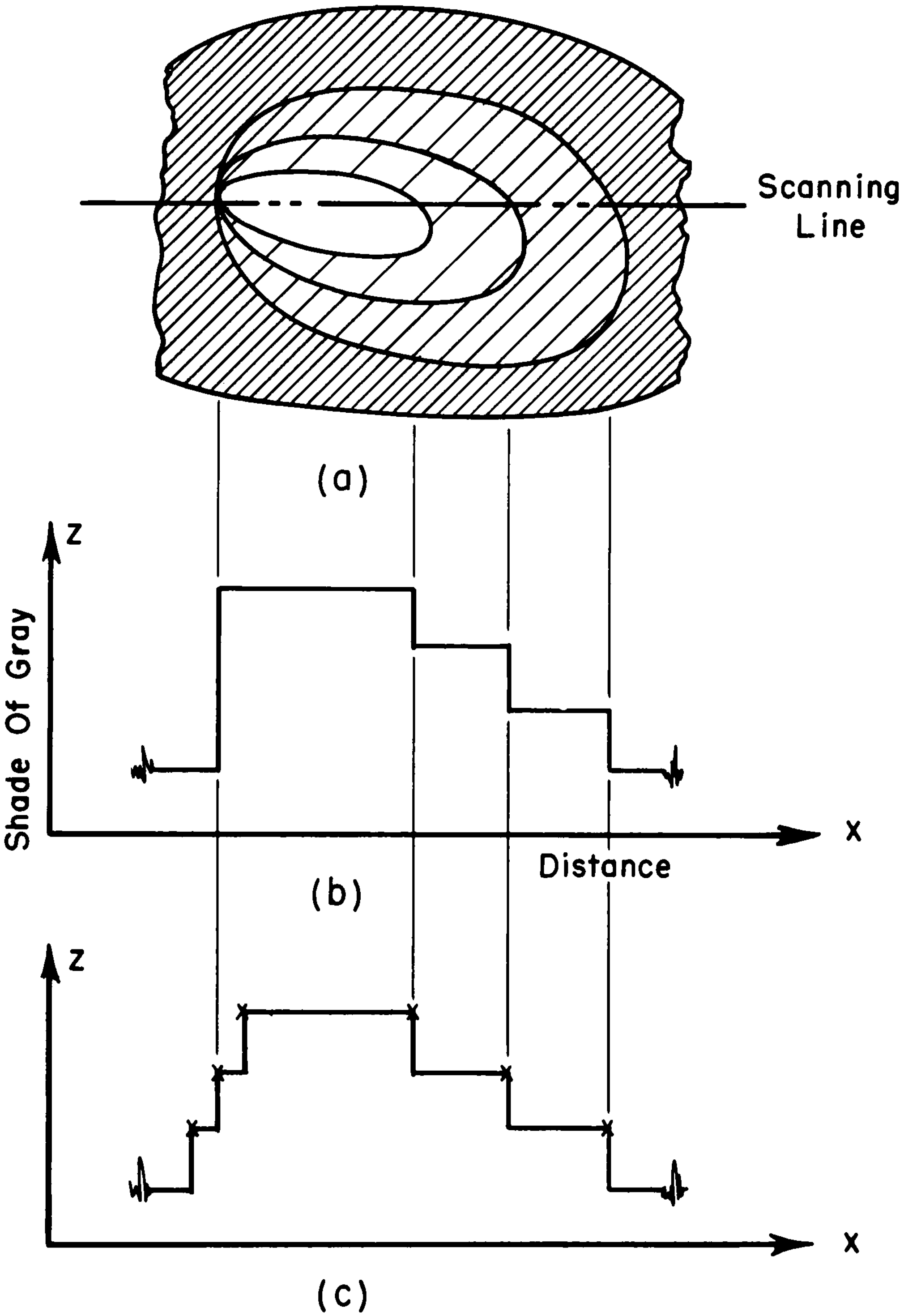


Fig. 7. Setting of fixed points. a) Section of quantized picture. b) Input step function produced by scanning. c) Fixed points for fitting smooth curve.

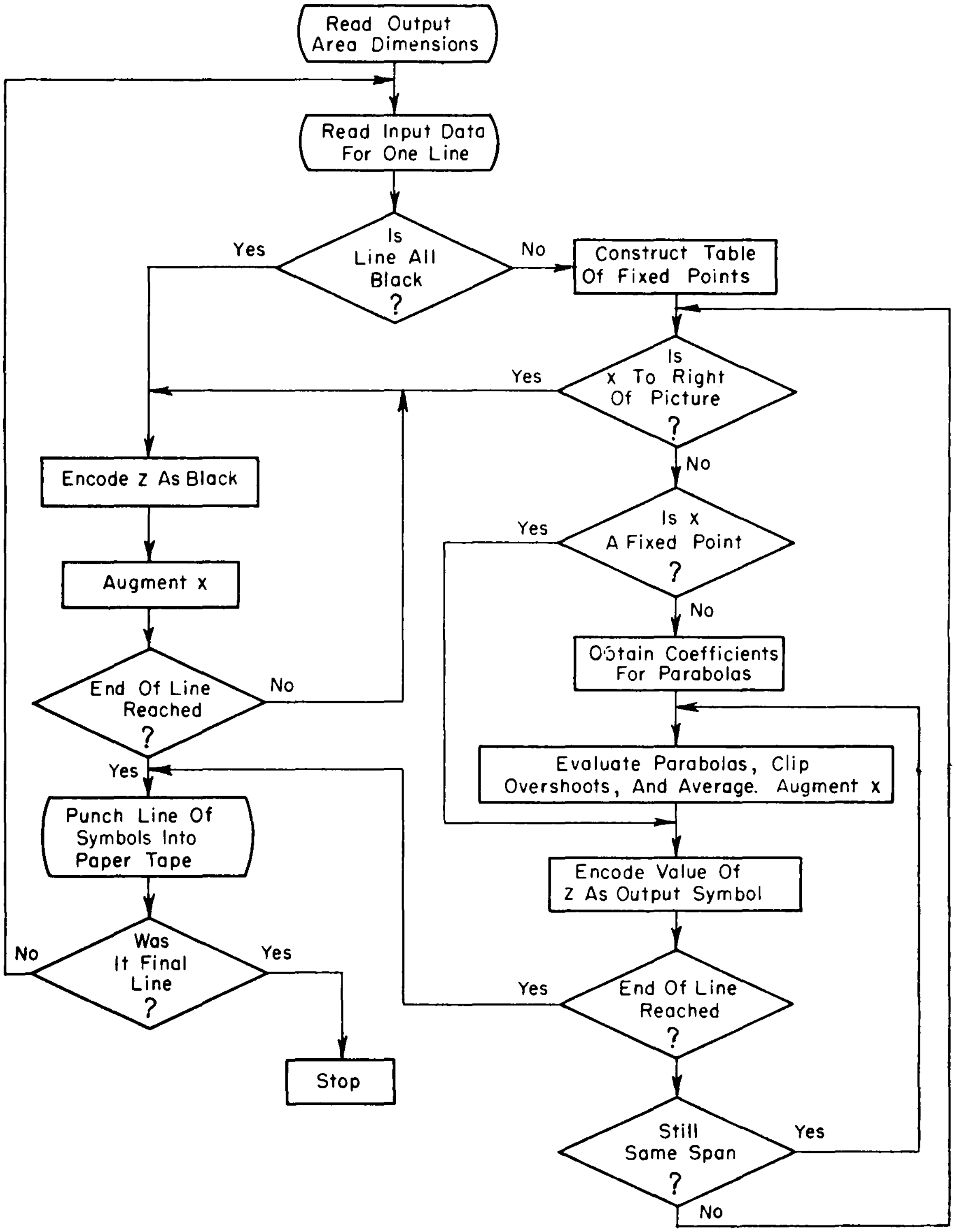


Fig. 8. Simplified computer flow diagram for smoothing picture by considering one line at a time.

The result of this first smoothing scheme is shown in Fig. 9. It was decided on the basis of this first result that the smoothing function used was reasonable, but that the fact that the scanning and smoothing had been done in one direction only introduced unpleasant streaking effects, most evident along the chin, along the temple, and in front of the ear. The cause of this streaking was clear: While great care had been taken to make the function and its derivative continuous along the scanning direction, the values it might assume along adjacent lines were computed completely independently. In most areas of the picture the change from line to line was small, amounting only to a slight shift in the relative locations of the fixed points. However, in some places one scanning line would cross contours in the quantized picture which the next line missed completely. A marked difference in the forms of the regenerating functions would result, unpleasantly evident in the typed picture.

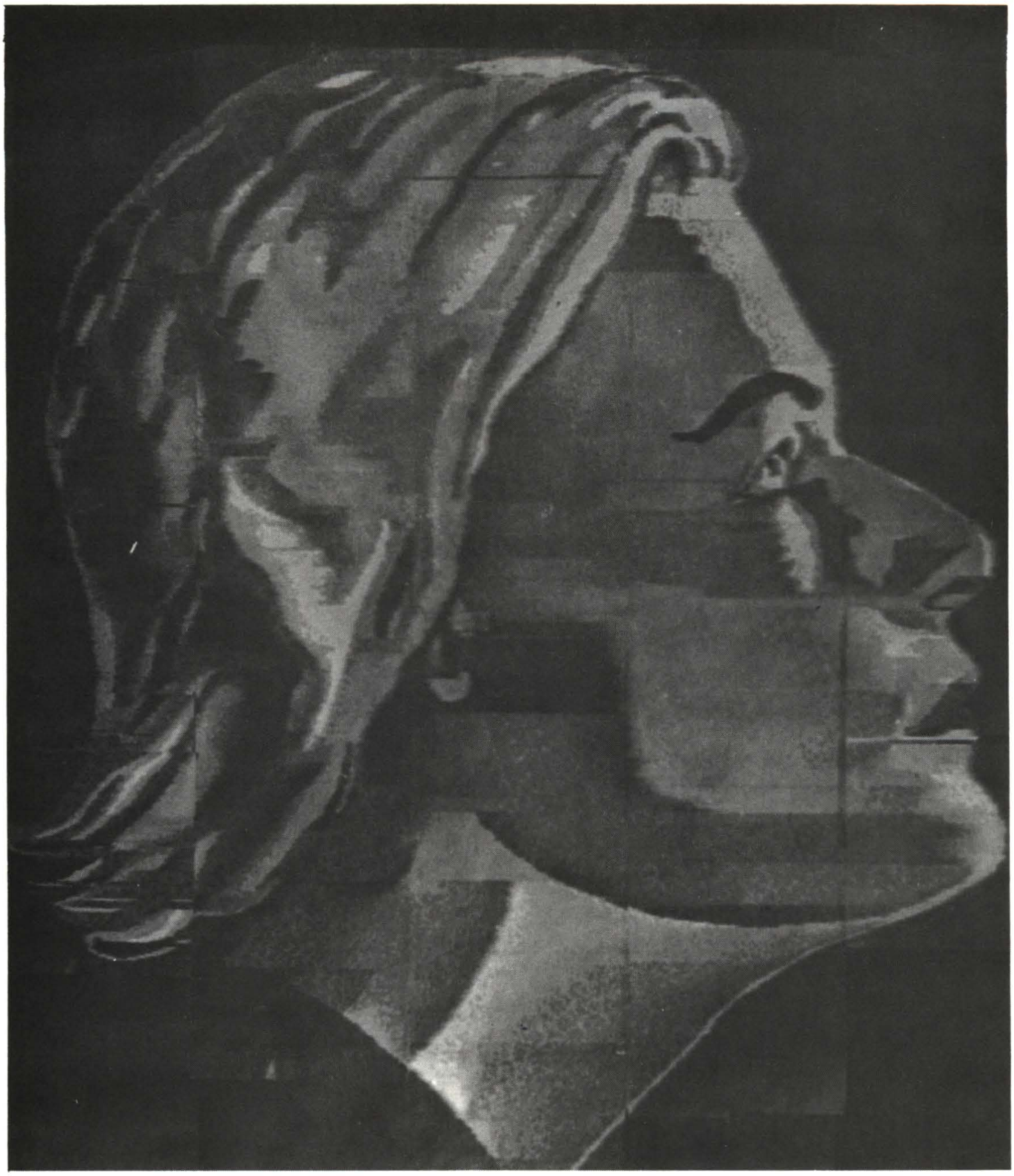


Fig. 9. Picture smoothed by considering one horizontal line at a time.

CHAPTER IV
REGENERATION SCHEME II

A computer program was written to reduce the streaking effects due to scanning in one direction only. The limitations imposed by the computer memory size (20,000 digits) and the desire to keep computing time within reasonable bounds precluded trying any truly two-dimensional smoothing scheme. Instead, it was decided to apply the scheme already used to both vertical and horizontal scans through the picture and to use the average of the two values obtained for each grid square as the output value to be encoded and typed.

A flow diagram of the computer program used is shown in Fig. 10. As a preliminary step, the data obtained by scanning the picture horizontally were used to generate the data that would have been obtained, had the picture been scanned vertically. The separate computer program written to do this punched the data into cards in the format of the original data deck. Both data decks were used by the smoothing program. First, the data representing the vertical scans were read, and the fixed points in the appropriate section of each line were generated and stored in memory. Then, the data from scanning horizontally were read one line at a time, calculations were made for the points in that line, and the code symbols were punched into paper tape. The necessity of storing in the computer

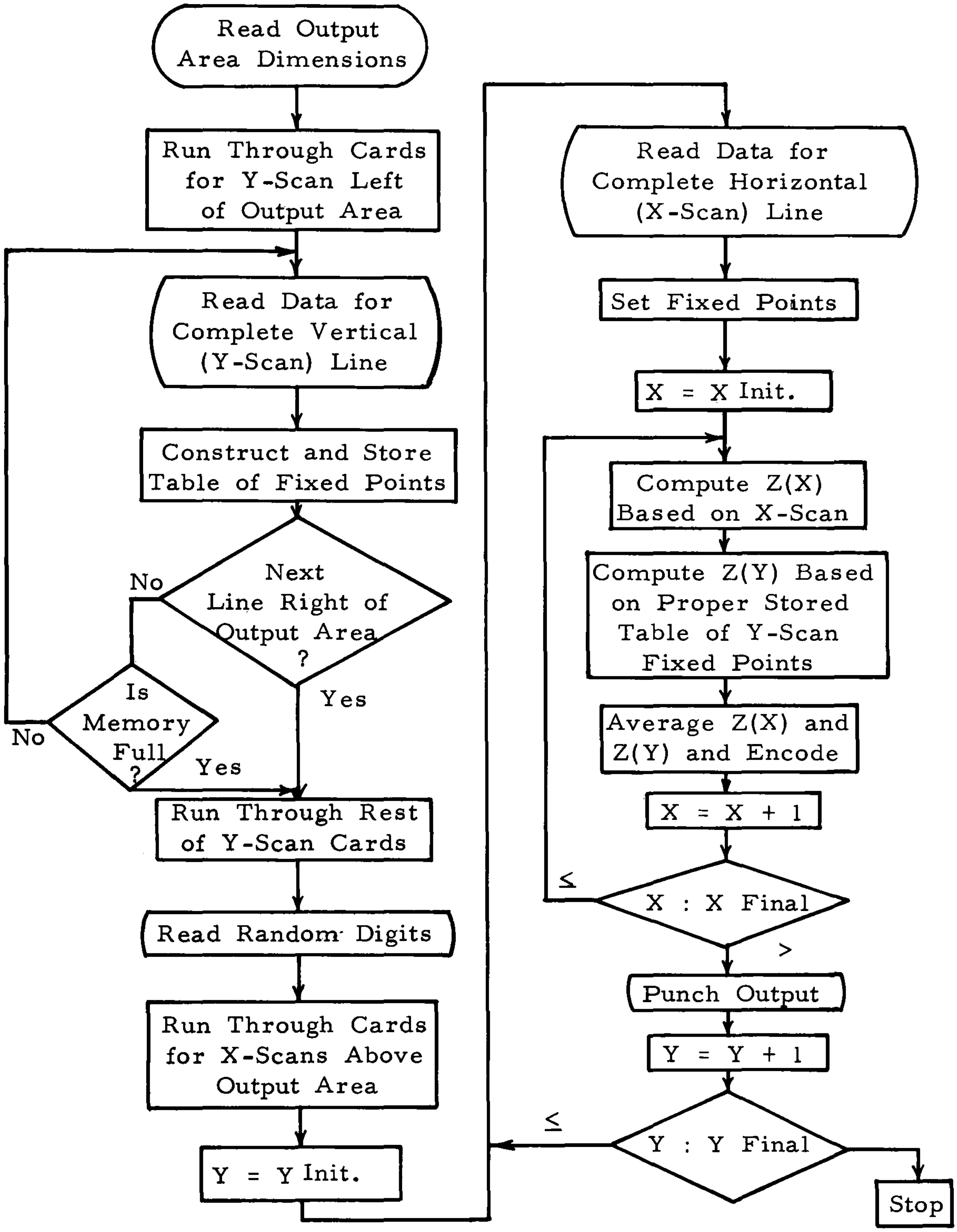


Fig. 10. Simplified flow diagram for smoothing picture along both horizontal and vertical scanning lines and averaging results.

memory all data due to the vertical scanning of the section of the picture to be smoothed placed definite limitations on the size of the piece that could be considered at one time. In practice, pieces 80 grid squares wide and 80 high were used, since these were reasonably close to the maximum and produced output that fitted conveniently on paper of standard size.

The result of this smoothing scheme is shown in Fig. 11. The mere averaging of one set of values for the shades of the picture having horizontal lines of discontinuity with another having vertical lines of discontinuity could not be expected to eliminate completely the streaking in either direction, but only to reduce the unpleasant effects. It can be seen from the picture that this indeed has been achieved in that the effect of streaking along the chin has been reduced to an acceptable level. The section of the picture near the ear is still rather bad, however, having now a vertical streak in addition to the somewhat attenuated dark horizontal streak.

Fig. 11. Picture smoothed on basis of both horizontal and vertical scans.

CHAPTER V

CONCLUSIONS

A. Results Obtained

The results of the investigation indicate that the principle of reducing a picture to its constant-intensity contours is sound. In the reconstructed picture the real physical boundaries in the object and the significant details - eyes, nostrils, lips, etc. - have been preserved with reasonable sharpness, while smooth graduations in shade have been introduced in the areas where they are appropriate.

In spite of limitations imposed by inaccurate quantizing and the badly nonuniform variations along the gray scale produced by the output device, the final result is quite acceptable to the eye. The relative independence of the result from the accurate spacing of the shades appears to be further verification of the well-known fact that the human eye is more sensitive to changes in light intensity than to absolute levels of illuminance.

Because of its complexity, the particular regeneration scheme employed can not be considered as a practical means of reconstructing images from their constant-intensity lines in any application where this needs to be done often. Furthermore, the most evident flaws in the reconstructed picture are the lines of discontinuity that have come about because smoothing was performed

along the scanning lines only. Since this investigation was undertaken principally to verify the validity of contour extraction as a means of economically storing the picture, these defects of the scheme were not serious in this application.

B. Future Work

Since the principle of reducing the essential information contained in a picture to contours of constant intensity has been shown to be sound, further work on improving the method is indicated.

The six quantizing levels used in this investigation appear to be a reasonable number, but their optimum spacing may be a function of the sensitivity of the human eye at various light intensity levels. Some trials should therefore be made employing test pictures more accurately quantized, in conjunction with an output device capable of producing a better gray scale. Type bars have been ordered to modify an existing "Flexowriter" to serve as such an output device.

The properties of the human eye may be taken into account further by processing the picture under consideration before quantizing it. Optical spatial prefiltering might be used to accentuate features significant to the human eye. The optical filter for this purpose would be designed to pass the low spatial frequencies passed by the eye and block high frequencies associated with detail beyond the resolving power of the eye.

The constant-intensity contours in an ordinary picture are somewhat arbitrary, and are highly sensitive to slight changes in quantizing level in those areas of the picture in which the shade variation is very gradual. Quantizing and regeneration may therefore greatly enhance some very slight fluctuations in shade that might happen to occur near a quantizing level that itself may not be very stable. It clearly is desirable to reduce noise of this type. At the same time, the possibility exists that a rather sharp change in shade in the original picture might go undetected by the quantizer if the total range of the transitions happens to lie entirely between two adjacent quantizing levels. As a result, a real physical boundary in the object represented may remain undetected.

Both types of error might be reduced by optical spatial prefiltering, before it is quantized, of the picture to be considered. The filter to be used would be an approximate two-dimensional analogue of a band-stop filter. Its function would be to accentuate sharp transitions while reducing very gradual ones and preserving the approximate shade levels for broad areas. The regenerating function could then be modified to incorporate the inverse of the prefilter characteristics, or this inverse might be taken by optical means.

REFERENCES

1. Haagen, W. F., "Video Bandwidth Compression," Master's Thesis, The Ohio State University, 1961.

BIBLIOGRAPHY

1. IBM Reference Manual, 1620 Data Processing System, International Business Machines Corporation, 1961.

2. 1620 Ohio State Assembly Program "OSAP" Reference Manual, Numerical Computation Laboratory, The Ohio State University.

ACKNOWLEDGEMENTS

The author wished to record his gratitude to Dr. Robert L. Cosgriff and Dr. Carlin F. Weimer for their guidance, suggestions, and encouragement.

The work reported in this thesis was supported in part by a contract between the Ohio State University Research Foundation and Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

APPENDIX

Programs for the IBM 1620 data processing system, written in the OSAP language

```
*  PROGRAM TO CONVERT DATA OBTAINED BY SCANNING
*  QUANTIZED PICTURE HORIZONTALLY TO A FORM
*  THAT WOULD BE OBTAINED BY SCANNING VERTICALLY
*  JURIS G RAUDSEPS, CALDWELL LAB 338, EXT 2507
*  OSU ANTENNA LAB, PROJECT 1222     JOB NO. 222.48
*
*     INPUT FORMAT-
*           YYY  XXXZ XXXZ  ...  XXXZ-
*     OUTPUT FORMAT-
*           XXXN YYYZ YYYZ  ...  YYYZ-
*     FLAGS ARE SET OVER HIGH-ORDER DIGITS OF
*     X AND Y FIELDS. N IS THE SEQUENCE NUMBER
*     OF CARDS WITH LIKE X. THE MACHINE OUTPUT
*     MUST BE SORTED SUCCESSIVELY ON COLUMNS
*     4,3,2, AND 1. RANGE OF X FOR OUTPUT
*     MUST ENTERED AS XINIT IN COLUMNS 1-3
*     AND XFINAL IN COLUMNS 6-8. (XLIM-XINIT)
*     MAX = 200. A CARD CONTAINING RECORD MARK
*     IN COLUMN 4 MUST BE PLACED AFTER INPUT DATA.
*
*
      DORG 402                                      00402
START RNCD CARD                                     00402 36 01530 00500
      SF   CARD                                     00414 32 01530 00000
      TF   XINIT,CARD+2                             00426 26 01613 01532
      SF   CARD+5                                   00438 32 01535 00000
      TF   XFINAL,CARD+7                            00450 26 01616 01537
*
*  SET UP OUTPUT CARD LOCATIONS, EACH PRECEDED
*  BY INDIRECT ADDRESS LOCATION TO ADDRESS
*  FIELDS WITHIN THAT CARD.
*
      TF   X,XINIT                                  00462 26 02027 01613
      TFM  IND,BLOCK+4                              00474 16 01621 02042
PT1   TF   ININD,IND                                00486 26 01626 01621
      SF   ININD                                    00498 32 01626 00000
      TF   IND,IND,6                                00510 26 0162J 01621
      AM   IND,3,610                                00522 11 0162J 00003
      TF   ININD,X,6                                00534 26 01620 02027
      AM   IND,1,610                                00546 11 0162J 00001
      TR   IND,CLEAR,6                              00558 31 0162J 01628
      AM   X,1,10                                   00570 11 02027 00001
      AM   IND,88,10                                00582 11 01621 000Q8
      C    X,XFINAL                                 00594 24 02027 01616
      BNH  PT1                                      00606 47 00486 01100
*
*  READ AND STORE DATA FROM SCANNING A COMPLETE LINE
      RNCD CARD                                     00618 36 01530 00500
PT2   TFM  N,INPUT                                  00630 16 02016 01711
      TF   Y,NEWNO                                  00642 26 02019 02024
PT3   TR   N,CARD+5,6                               00654 31 02010 01535
      AM   N,75,10                                  00666 11 02016 000P5
      RNCD CARD                                     00678 36 01530 00500
      C    NEWNO,Y                                  00690 24 02024 02019
      BE   PT3                                      00702 46 00654 01200
*
*  BEGIN SEARCH FOR TRANSITIONS
*
      TF   X,XINIT                                  00714 26 02027 01613
      TFM  IND,BLOCK+4                              00726 16 01621 02042
      TDM  SENSE,0,11,    NO FLAG IN SENSE MEANS    00738 15 02028 00000
      TFM  N,INPUT+2,,    X IS TO RIGHT FO PICTURE  00750 16 02016 01713
```

```
       TFM  NMOD,INPUT-2                             00762 16 02033 01709 12-0063
*  ESTABLISH Z(X)                                                         0064
*                                                                         0065
PT10   BNF  PT6,SENSE                                00774 44 01026 02028 12-0066
       C    X,N,11                                   00786 24 02027 02010 12-0067
       BL   PT11                                     00798 47 01014 01300 12-0068
       BE   PT5                                      00810 46 00978 01200 12-0069
*                                                                         0070
*  SEARCH FOR PROPER SPAN IN INPUT TABLE                                  0071
*                                                                         0072
*  CHECK IF X IS BEYOND PICTURE                                           0073
PT4    AM   N,2,10                                   00822 11 02016 00002 12-0074
       BNF  PT12,N,11                                00834 44 00882 02010 12-0075
       TDM  SENSE,0,, PROVIDE FOR BYPASS OF          00846 15 02028 00000 12-0076
       TDM  Z,0,,        SEARCH ROUTINE              00858 15 02035 00000 12-0077
       B    PT6                                      00870 49 01026 00000 12-0078
*  CHECK IF X IS IN NEXT INPUT SPAN                                       0079
PT12   AM   N,3,10                                   00882 11 02016 00003 12-0080
       C    X,N,11                                   00894 24 02027 02010 12-0081
       BH   PT4,,,   NO                              00906 46 00822 01100 12-0082
       BE   PT5,,,   NO                              00918 46 00978 01200 12-0083
       TF   NMOD,N                                   00930 26 02033 02016 12-0084
       SM   NMOD,4                                   00942 12 02033 00004 12-0085
       TD   Z,NMOD,11                                00954 25 02035 0203L 12-0086
       B    PT6                                      00966 49 01026 00000 12-0087
*  Z(X,Y) IS GIVEN EXPLICITLY BY INPUT                                    0088
PT5    TF   NMOD,N                                   00978 26 02033 02016 12-0089
       AM   NMOD,1                                   00990 11 02033 00001 12-0090
       AM   N,5                                      01002 11 02016 00005 12-0091
PT11   TD   Z,NMOD,11                                01014 25 02035 0203L 12-0092
*                                                                         0093
*  ENTER TRANSITION IN OUTPUT CARD IF Z(X,Y)                              0094
*   IS DIFFERENT FROM Z(X,Y-1)                                            0095
*                                                                         0096
PT6    TF   ININD,IND                                01026 26 01626 01621 12-0097
       SF   ININD                                    01038 32 01626 00000 12-0098
       TD   ZP,ININD,11                              01050 25 02037 01620 12-0099
       C    Z,ZP                                     01062 24 02035 02037 12-0100
       BE   PT8                                      01074 46 01230 01200 12-0101
       AM   IND,4,610                                01086 11 0162J 00004 12-0102
       BNR  PT7,ININD,11                             01098 45 01194 01620 12-0103
*                                                                         0104
*  IF OUTPUT CARD FULL,PUNCH AND START NEW CARD                           0105
*                                                                         0106
       TF   IND,IND,6                                01110 26 0162J 01621 12-0107
       AM   IND,4,610                                01122 11 0162J 00004 12-0108
       AM   ININD,1,610, AUGMENT CARD SEQ. NO.       01134 11 01620 00001 12-0109
       SM   IND,3,610                                01146 12 0162J 00003 12-0110
       WNCD IND,,6                                   01158 38 0162J 00400 12-0111
       AM   IND,7,10                                 01170 11 01621 00007 12-0112
       TR   IND,CLEAR+4,6                            01182 31 0162J 01632 12-0113
*                                                                         0114
*  ADD NEW ENTRY TO OUTPUT CARD                                           0115
*                                                                         0116
PT7    TF   ININD,X,6                                01194 26 01620 02027 12-0117
       AM   IND,1,6                                  01206 11 0162J 00001 12-0118
       TD   ININD,Z,6                                01218 25 01620 02035 12-0119
*                                                                         0120
*  LOOP BACK FOR NEXT PT OR NEXT LINE IF NEC.                             0121
*                                                                         0122
PT8    AM   X,1,10                                   01230 11 02027 00001 12-0123
       AM   IND,88,10                                01242 11 01621 00088 12-0124
       C    X,XFINAL                                 01254 24 02027 01616 12-0125
       BNH  PT10                                     01266 47 00774 01100 12-0126
```

```
        BNR   PT3,NEWNO+1                                01278 45 00654 02025 12-0127
*                                                                             0128
*  ALL INPUT READ AND CONVERTED                                               0129
*    PUT END-OF-LINE FLAGS INTO CARDS AND PUNCH OUT                           0130
*                                                                             0131
        TF    X,XINIT                                    01290 26 02027 01613 12-0132
        TFM   IND,BLOCK+4                                01302 16 01621 02042 12-0133
PT9     TF    ININD,IND                                  01314 26 01626 01621 12-0134
        SF    ININD                                      01326 32 01626 00000 12-0135
        AM    IND,1,610                                  01338 11 0162J 00001 12-0136
        TF    N,IND,, POSITION FLAG IF NO PTS THIS LI    01350 26 02016 01621 12-0137
        AM    N,5,10                                     01362 11 02016 00005 12-0138
        C     IND,N,6                                    01374 24 0162J 02016 12-0139
        BH    *+24                                       01386 46 01410 01100 12-0140
        AM    IND,5,610                                  01398 11 0162J 00005 12-0141
        TDM   ININD,0,611                                01410 15 01620 00000 12-0142
        AM    IND,4,10                                   01422 11 01621 00004 12-0143
        AM    IND,1,610                                  01434 11 0162J 00001 12-0144
        SM    IND,3,10                                   01446 12 01621 00003 12-0145
        WNCD  IND,,6                                     01458 38 0162J 00400 12-0146
        AM    X,1,10                                     01470 11 02027 00001 12-0147
        AM    IND,87,10                                  01482 11 01621 00007 12-0148
        C     X,XFINAL                                   01494 24 02027 01616 12-0149
        BNH   PT9                                        01506 47 01314 01100 12-0150
        H                                                01518 48 00000 00000 12-0151
*                                                                             0152
CARD    DSB   1,80,, INPUT AREA                          01530          00080  0153
REC     DC    1,-                                        01610 Z        01610 01-0154
XINIT   DS    3                                          01613          00003  0155
XFINAL  DS    3                                          01616          00003  0156
IND     DS    5,,ADDRESS OF OUTPUT LOC. ADDR.            01621          00005  0157
ININD   DS    5,,INTERMEDIATE INDIRECT OUTPUT ADDR.      01626          00005  0158
CLEAR   DC    2,0                                        01627 00       01628 02-0159
CLRB    DNB   76                                         01704          00076  0160
                                                         01629 -- ----------- 12-0161
                                                         01641 -- ----------- 12-0162
                                                         01653 -- ----------- 12-0163
                                                         01665 -- ----------- 12-0164
                                                         01677 -- ----------- 12-0165
                                                         01689 -- ----------- 12-0166
                                                         01701 -- --    -     04-0167
CLRC    DC    3,00-                                      01705 00 Z     01707 03-0168
SPACE   DC    3,0                                        01708 00 0     01710 03-0169
INPUT   DSB   1,301                                      01711          00301  0170
N       DS    5,,ADDRESS WITHIN INPUT TABLE              02016          00005  0171
Y       DS    3                                          02019          00003  0172
NEWNO   DSA   CARD+2                                     02020 01 532         05-0173
X       DS    3                                          02027          00003  0174
SENSE   DS    1                                          02028          00001  0175
NMOD    DS    5                                          02033          00005  0176
Z       DC    2,0                                        02034 00       02035 02-0177
ZP      DC    2,0                                        02036 00       02037 02-0178
BLOCK   DS    ,ZP+1                                      02038          00000  0179
        DEND  START                                      00402                 0180
L60010000500J50040000007L60000000500M90003600000   00192 M6 00220 01200 J2001Q1
0000000000001020304000204060800030609021004080216100500151020060218142007040018
520353045403632748445532494653604842 L60017500500L10025000000L60002000500   00183
112820080614223009081726300000000000506070809001214161815181124272024282236300184
6546275445362718Z L10028400020J50030000000M900402000M90003800000           00185
```

```
*  PROGRAM TO SMOOTH QUANTIZED PICTURE                                      0001
*  JURIS G RAUDSEPS, CALDWELL LAB 338, EXT. 2507                            0002
*  OSU ANTENNA LAB PROJECT 1222, NCL JOB. NO. 222.48                        0003
*                                                                           0004
*       THIS PROGRAM SMOOTHS QUANTIZED PICTURE BY FITTING SMOOTH CURVES     0005
*       THROUGH STEP FUNCTION DATA (OBTAINED BY SCANNING PARALLEL           0006
*       TO X AND Y AXES) AND AVERAGING VALUES AT EVERY INTERSECTION OF      0007
*       SCANNING LINES. OUTPUT IS SYMBOLS ON PAPER TAPE THAT WILL GIVE      0008
*       PICTURE IF READ BY SPECIAL AUTOMATIC TYPEWRITER.                    0009
*    INPUT=                                                                 0010
*       CARD CONTAINING OUTPUT BLOCK DIMENSIONS=                            0011
*            YINIT (COL 1-3), YFINAL (COL 6-8)                              0012
*            XINIT (COL 11-13), XFINAL (COL 16-18)                          0013
*            NO FLAGS NEEDED. PROGRAM MAY REDUCE XFINAL                     0014
*       DECK OF DATA SCANNING IN Y DIRECTION                                0015
*       THREE CARDS OF RANDOM DIGITS                                        0016
*       DECK OF DATA SCANNING IN X DIRECTION                                0017
*                                                                           0018
*                                                                           0019
       DORG 402                                   00402                     0020
SPACE  DC    2,0                                  00402 00       00403 02-0021
*  READ OUTPUT BLOCK DIMENSIONS                                             0022
START  RNCD CARD                                  00404 36 07122 00500 12-0023
       SF    CARD                                 00416 32 07122 00000 12-0024
       TF    YINIT,CARD+2                         00428 26 01039 07124 12-0025
       SF    CARD+5                               00440 32 07127 00000 12-0026
       TF    YFINAL,CARD+7                        00452 26 01123 07129 12-0027
       SF    CARD+10                              00464 32 07132 00000 12-0028
       TF    XINIT,CARD+12                        00476 26 01183 07134 12-0029
       SF    CARD+15                              00488 32 07137 00000 12-0030
       TF    XFINAL,CARD+17                       00500 26 01195 07139 12-0031
*  FIND PROPER DATA CARD TO START                                           0032
       RNCD CARD                                  00512 36 07122 00500 12-0033
       C     NEWNO,XINIT                          00524 24 07124 01183 12-0034
       BNF   *-24                                 00536 47 00512 01200 12-0035
*  CONSTRUCT ALPHAMERIC END MESSAGE                                         0036
       TD    MSG+2*3,YINIT-2                      00548 25 07211 01037 12-0037
       TD    MSG+2*4,YINIT-1                      00560 25 07213 01038 12-0038
       TD    MSG+2*5,YINIT                        00572 25 07215 01039 12-0039
       TD    MSG+2*10,YFINAL-2                    00584 25 07225 01121 12-0040
       TD    MSG+2*11,YFINAL-1                    00596 25 07227 01122 12-0041
       TD    MSG+2*12,YFINAL                      00608 25 07229 01123 12-0042
       TD    MSG+2*18,XINIT-2                     00620 25 07241 01181 12-0043
       TD    MSG+2*19,XINIT-1                     00632 25 07243 01182 12-0044
       TD    MSG+2*20,XINIT                       00644 25 07245 01183 12-0045
*  CONSTRUCT TABLES OF FIXED PTS FOR Y SCANS                                0046
       TF    X,XINIT                              00656 26 01356 01183 12-0047
       TF    WINIT,YINIT                          00668 26 01506 01039 12-0048
       TF    WFINAL,YFINAL                        00680 26 01359 01123 12-0049
       TFM   ZOFYAD,BLOCK+4                       00692 16 01526 07556 12-0050
INPUT  DS    ,*-300, WRITE OVER PROGRAM ABOVE     00403          00000    0051
M1     BTM   FIXPTS,,10                           00704 17 01364 00000 12-0052
       SM    J,YTABLE-5                           00716 12 05283 07276 12-0053
       TF    TEMP1,ZOFYAD                         00728 26 04063 01526 12-0054
       AM    ZOFYAD,1,10                          00740 11 01526 00001 12-0055
       TR    ZOFYAD,YTABLE,6                      00752 31 01520 07281 12-0056
       A     ZOFYAD,J                             00764 21 01526 05283 12-0057
       TF    TEMP1,ZOFYAD,6                       00776 26 04063 01526 12-0058
       CM    ZOFYAD,19740                         00788 14 01526 19740 12-0059
       BNH   M2                                   00800 47 00836 01100 12-0060
       TF    XFINAL,X                             00812 26 01195 01356 12-0061
       B     M3                                   00824 49 00872 00000 12-0062
```

```
M2      AM    X,1,10                                       00836 11 01356 00001 12-0063
        C     X,XFINAL                                     00848 24 01356 01195 12-0064
        BNH   M1                                           00860 47 00704 01100 12-0065
*  SET XFINAL INTO END MESSAGE                                                     0066
M3      TD    MSG+2*25,XFINAL-2                            00872 25 07255 01193 12-0067
        TD    MSG+2*26,XFINAL-1                            00884 25 07257 01194 12-0068
        TD    MSG+2*27,XFINAL                              00896 25 07259 01195 12-0069
*  RUN THROUGH REST OF Y-SCAN DECK                                                 0070
        RNCD  RANDOM                                       00908 36 00704 00500 12-0071
        BNF   *+24,RANDOM                                  00920 44 00944 00704 12-0072
        B     *-24                                         00932 49 00908 00000 12-0073
RANDOM  DS    ,M1,WRITE OVER PROGRAM ABOVE                 00704          00000    0074
*  READ RANDOM DIGITS                                                              0075
ORIG    RNCD  RANDOM+80                                    00944 36 00784 00500 12-0076
        RNCD  RANDOM+160                                   00956 36 00864 00500 12-0077
*                                                                                  0078
*COMPUTE OUTPUT, LINE BY LINE                                                      0079
*                                                                                  0080
        TF    WINIT,XINIT                                  00968 26 01506 01183 12-0081
        TF    WFINAL,XFINAL                                00980 26 01359 01195 12-0082
*  FIND PROPER PLACE IN X-SCAN DECK                                                0083
        RNCD  CARD                                         00992 36 07122 00500 12-0084
        C     NEWNO,YINIT                                  01004 24 07124 01039 12-0085
        BNE   *-24                                         01016 47 00992 01200 12-0086
*  READ X-SCAN LINE AND SET FIXED POINTS                                           0087
M4      BTM   FIXPTS,,,(YINIT IN Q)                        01028 17 01364 00000 12-0088
*  ESTABLISH INITIAL VALUES TO START LINE                                          0089
        TF    X,XINIT                                      01040 26 01356 01183 12-0090
        TFM   YLNAD,BLOCK+4                                01052 16 01147 07556 12-0091
*  GO TO ROUTINE TO COMPUTE Z(X)                                                   0092
M6      TF    W,X                                          01064 26 04803 01356 12-0093
        TFM   REF,YTABLE-1                                 01076 16 01531 07280 12-0094
        TFM   Z,0,8                                        01088 16 04407 00000 12-0095
        TFM   EXIT,*+24                                    01100 16 05794 01124 12-0096
M6A     B     COMP,,,            (YFINAL IN Q)             01112 49 04348 00000 12-0097
*  GO TO ROUTINE TO COMPUTE Z(Y)                                                   0098
        TF    W,Y                                          01124 26 04803 05103 12-0099
M6E     TFM   REF,,,             (YLNAD IN Q)              01136 16 01531 00000 12-0100
        TF    YLNAD,YLNAD,11,ADDRESS OF NEXT TABLE         01148 26 01147 0114P 12-0101
        TFM   EXIT,*+24                                    01160 16 05794 01184 12-0102
M6B     B     COMP,,,(XINIT IN Q)                          01172 49 04348 00000 12-0103
*  ENCODE OUTPUT                                                                   0104
M6C     BTM   ENCODE,,,(XFINAL IN Q)                       01184 17 04064 00000 12-0105
        AM    X,1,10                                       01196 11 01356 00001 12-0106
        C     X,XFINAL                                     01208 24 01356 01195 12-0107
        BNH   M6                                           01220 47 01064 01100 12-0108
*  END LINE AND PUNCH                                                              0109
        SM    OUTAD,1,10                                   01232 12 04575 00001 12-0110
        TR    OUTAD,ENDWHT-1,6                             01244 31 0457N 07262 12-0111
        BD    *+24,Y                                       01256 43 01280 05103 12-0112
        TR    OUTAD,ENDBLK-1,6                             01268 31 0457N 07268 12-0113
        WAPT  OUTPUT                                       01280 39 00403 00200 12-0114
        TFM   OUTAD,OUTPUT                                 01292 16 04575 00403 12-0115
        AM    Y,1,10                                       01304 11 05103 00001 12-0116
*  END PROGRAM                                                                     0117
        C     Y,YFINAL                                     01316 24 05103 01123 12-0118
        BNH   M4                                           01328 47 01028 01100 12-0119
        WATY  MSG                                          01340 39 07205 00100 12-0120
M6D     H     ,,,(X,WFINAL,FIELD DUE TO BTM FIXPTS)        01352 48 00000 00000 12-0121
*                                                                                  0122
```

```
*                                                                          0123
*           S U B R O U T I N E S                                          0124
*                                                                          0125
*SUBROUTINE TO READ LINE AND SET FIXED POINTS                              0126
*                                                                          0127
*  READ COMPLETE LINE                                                      0128
FIXPTS TFM  TEMP1,INPUT                     01364 16 04063 00403 12-0129
       TF   Y,NEWNO                         01376 26 05103 07124 12-0130
       TR   TEMP1,CARD+5,6                  01388 31 0406L 07127 12-0131
       RNCD CARD                            01400 36 07122 00500 12-0132
       AM   TEMP1,75,10                     01412 11 04063 000P5 12-0133
       C    NEWNO,Y                         01424 24 07124 05103 12-0134
       BE   FIXPTS+24                       01436 46 01388 01200 12-0135
*  SET FIXED POINTS                                                        0136
       TFM  J,YTABLE+52                     01448 16 05283 07333 12-0137
       TFM  J,0,69                          01460 16 0528L 00000 12-0138
       TFM  N,INPUT+4                       01472 16 06718 00407 12-0139
       BNF  SA1-12,N,11                     01484 44 01532 0671Q 12-0140
*  IF NO FIXED POINTS NEED BE SET                                          0141
SA3    TDM  YTABLE+4,0,,(WINIT IN Q-1)      01496 15 07285 00000 12-0142
RM2    DC   1,-,*                           01507 Z          01507 01-0143
       TFM  J,YTABLE+4                      01508 16 05283 07285 12-0144
SA3A   BB   ,,,(ZOFYAD,REF)                 01520 42 00000 00000 12-0145
       TFM  YTABLE+4,0                      01532 16 07285 00000 12-0146
SA1    SM   N,2,10                          01544 12 06718 00002 12-0147
       C    N,WINIT,6                       01556 24 0671Q 01506 12-0148
       BNL  SA2                             01568 46 01640 01300 12-0149
       AM   N,7,10                          01580 11 06718 00007 12-0150
*  SEARCH FOR PROPER FIRST SPAN                                            0151
       BNF  SA1,N,11                        01592 44 01544 0671Q 12-0152
       SM   N,2,10                          01604 12 06718 00002 12-0153
       C    N,WINIT,6                       01616 24 0671Q 01506 12-0154
       BNH  SA3                             01628 47 01496 01100 12-0155
*  SPECIAL TREATMENT NECESSARY FOR 1ST INPUT SPAN                          0156
SA2    CM   N,INPUT+2                       01640 14 06718 00405 12-0157
       BNH  PT9-12                          01652 47 01712 01100 12-0158
       SM   N,5,10                          01664 12 06718 00005 12-0159
       CM   N,INPUT+2                       01676 14 06718 00405 12-0160
       BNH  *+24                            01688 47 01712 01100 12-0161
       SM   N,5,9                           01700 12 06718 00005 12-0162
       AM   N,1,9                           01712 11 06718 00001 12-0163
*9  COMPUTE SIZE OF STEP                                                   0164
PT9    TF   NMOD,N                          01724 26 06723 06718 12-0165
       SM   NMOD,5                          01736 12 06723 00005 12-0166
       TFM  D,0,10                          01748 16 07075 00000 12-0167
       TD   D,N,11                          01760 25 07075 0671Q 12-0168
       TFM  DA,0,10                         01772 16 07077 00000 12-0169
       TD   DA,NMOD,11                      01784 25 07077 0672L 12-0170
       S    D,DA                            01796 22 07075 07077 12-0171
*10 CLEAR TEMP PLACE FOR NEW POINTS                                        0172
       TR   M-3,CLRM-20                     01808 31 00001 07531 12-0173
       TFM  MAD,M                           01820 16 02071 00004 12-0174
       TF   DA,D                            01832 26 07077 07075 12-0175
       TD   MAD,NMOD,611                    01844 25 0207J 0672L 12-0176
       BNF  PT11-12,D                       01856 44 01964 07075 12-0177
*13 TRANSITION DOWN, SET LEVELS ONE BY ONE                                 0178
PT13   AM   D,1,10                          01868 11 07075 00001 12-0179
       CM   D,0,10                          01880 14 07075 00000 12-0180
       BE   PT12                            01892 46 02072 01200 12-0181
       TF   MMOD,MAD                        01904 26 05007 02071 12-0182
       AM   MAD,4                           01916 11 02071 00004 12-0183
       TD   MAD,MMOD,611                    01928 25 0207J 0500P 12-0184
       SM   MAD,1,610                       01940 12 0207J 00001 12-0185
       B    PT13                            01952 49 01868 00000 12-0186
```

```
*11 IF TRANSITION IS UPWARD                                              0187
        AM      MAD,1,610                    01964 11 0207J 00001 12-0188
*12 IF NECESSART, SET ONE MORE LEVEL UP                                  0189
PT11    SM      D,1,10                       01976 12 07075 00001 12-0190
        CM      D,0,10                       01988 14 07075 00000 12-0191
        BE      PT12                         02000 46 02072 01200 12-0192
        TF      MMOD,MAD                     02012 26 05007 02071 12-0193
        AM      MAD,4                        02024 11 02071 00004 12-0194
        TD      MAD,MMOD,611                 02036 25 0207J 0500P 12-0195
        AM      MAD,1,610                    02048 11 0207J 00001 12-0196
        B       PT11                         02060 49 01976 00000 12-0197
PT12    AM      MAD,1                        02072 11 02071 00001 12-0198
        TD      MAD,400,6                    02084 25 0207J 00400 12-0199
*14 ASSIGN PROPER X COORDINATES                                          0200
        SM      N,1                          02096 12 06718 00001 12-0201
        CF      DA                           02108 33 07077 00000 12-0202
        CM      DA,1,10                      02120 14 07077 00001 12-0203
        BE      PT14                         02132 46 02672 01200 12-0204
        CM      DA,3,10                      02144 14 07077 00003 12-0205
        BE      PT15                         02156 46 02804 01200 12-0206
        CM      DA,5,10                      02168 14 07077 00005 12-0207
        BE      PT16                         02180 46 03080 01200 12-0208
*15 STEP IS 2 OR 4, THUS OFF-CENTER                                      0209
        CM      N,INPUT+2                    02192 14 06718 00405 12-0210
        BE      PT17,,,FIRST TRANSITION ONLY 02204 46 02432 01200 12-0211
        TF      NMOD,N                       02216 26 06723 06718 12-0212
        AM      NMOD,2,10                    02228 11 06723 00002 12-0213
        BNF     *+24,NMOD,11                 02240 44 02264 0672L 12-0214
        B       PT17A                        02252 49 02360 00000 12-0215
        SM      NMOD,7                       02264 12 06723 00007 12-0216
        TF      BS,N,11                      02276 26 05367 0671Q 12-0217
        S       BS,NMOD,11                   02288 22 05367 0672L 12-0218
        AM      NMOD,10                      02300 11 06723 00010 12-0219
        TF      FS,NMOD,11                   02312 26 05355 0672L 12-0220
        S       FS,N,11                      02324 22 05355 0671Q 12-0221
        C       BS,FS                        02336 24 05367 05355 12-0222
        BH      PT17                         02348 46 02432 01100 12-0223
*16 FRONT SPAN LONGER                                                    0224
PT17A   CM      DA,2,10                      02360 14 07077 00002 12-0225
        BNF     PT18                         02372 47 03488 01200 12-0226
        TF      X1,N,11                      02384 26 00003 0671Q 12-0227
        TF      X2,N,11                      02396 26 00007 0671Q 12-0228
        AM      X2,1,9                       02408 11 00007 00001 12-0229
        B       PT19                         02420 49 02492 00000 12-0230
*17 BACK SPAN LONGER                                                     0231
PT17    CM      DA,2,10                      02432 14 07077 00002 12-0232
        BNF     PT20                         02444 47 03548 01200 12-0233
        TF      X1,N,11                      02456 26 00003 0671Q 12-0234
        SM      X1,1,9                       02468 12 00003 00001 12-0235
        TF      X2,N,11                      02480 26 00007 0671Q 12-0236
*18 ADD PTS TO TABLE, STEP OF 2                                          0237
PT19    C       X1,J,11                      02492 24 00003 0528L 12-0238
        BH      PT21                         02504 46 02612 01100 12-0239
        SM      J,4                          02516 12 05283 00004 12-0240
        C       X1,J,11                      02528 24 00003 0528L 12-0241
        BH      PT21                         02540 46 02612 01100 12-0242
        TF      JMOD,J                       02552 26 05715 05283 12-0243
        AM      JMOD,2                       02564 11 05715 00002 12-0244
        TR      JMOD,X2-2,6                  02576 31 0571N 00005 12-0245
        AM      J,4                          02588 11 05283 00004 12-0246
        B       PT8                          02600 49 03932 00000 12-0247
PT21    TF      JMOD,J                       02612 26 05715 05283 12-0248
        AM      JMOD,2                       02624 11 05715 00002 12-0249
        TR      JMOD,X1-2,6                  02636 31 0571N 00001 12-0250
```

```
        AM    J,8                                    02648 11 05283 00008 12-0251
        B     PT8                                    02660 49 03932 00000 12-0252
*19 STEP OF ONE                                                            0253
PT14    TF    X1,N,11                                02672 26 00003 0671Q 12-0254
        C     X1,J,11                                02684 24 00003 0528L 12-0255
        BH    PT22                                   02696 46 02744 01100 12-0256
        BE    PT8                                    02708 46 03932 01200 12-0257
        SM    J,4                                    02720 12 05283 00004 12-0258
        B     PT8                                    02732 49 03932 00000 12-0259
PT22    TF    JMOD,J                                 02744 26 05715 05283 12-0260
        AM    JMOD,2                                 02756 11 05715 00002 12-0261
        TR    JMOD,X1-2,6                            02768 31 0571N 00001 12-0262
        AM    J,4                                    02780 11 05283 00004 12-0263
        B     PT8                                    02792 49 03932 00000 12-0264
*20 STEP OF THREE                                                          0265
PT15    TF    X1,N,11                                02804 26 00003 0671Q 12-0266
        SM    X1,1,9                                 02816 12 00003 00001 12-0267
        TF    X2,N,11                                02828 26 00007 0671Q 12-0268
        TF    X3,N,11                                02840 26 00011 0671Q 12-0269
        AM    X3,1,9                                 02852 11 00011 00001 12-0270
        C     X1,J,11                                02864 24 00003 0528L 12-0271
        BL    PT23                                   02876 47 02972 01300 12-0272
        BNE   PT24                                   02888 47 02912 01200 12-0273
        SM    J,4                                    02900 12 05283 00004 12-0274
PT24    TF    JMOD,J                                 02912 26 05715 05283 12-0275
        AM    JMOD,2                                 02924 11 05715 00002 12-0276
        TR    JMOD,X1-2,6                            02936 31 0571N 00001 12-0277
        AM    J,12                                   02948 11 05283 00012 12-0278
        B     PT8                                    02960 49 03932 00000 12-0279
PT23    C     X2,J,11                                02972 24 00007 0528L 12-0280
        BL    PT25                                   02984 47 03056 01300 12-0281
        SM    J,4                                    02996 12 05283 00004 12-0282
PT26    TF    JMOD,J                                 03008 26 05715 05283 12-0283
        AM    JMOD,2                                 03020 11 05715 00002 12-0284
        TR    JMOD,X2-2,6                            03032 31 0571N 00005 12-0285
        B     PT8                                    03044 49 03932 00000 12-0286
PT25    SM    J,8                                    03056 12 05283 00008 12-0287
        B     PT26                                   03068 49 03008 00000 12-0288
*21 STEP OF FIVE                                                           0289
PT16    TF    X1,N,11                                03080 26 00003 0671Q 12-0290
        SM    X1,2,9                                 03092 12 00003 00002 12-0291
        TF    X2,N,11                                03104 26 00007 0671Q 12-0292
        SM    X2,1,9                                 03116 12 00007 00001 12-0293
        TF    X3,N,11                                03128 26 00011 0671Q 12-0294
        TF    X4,N,11                                03140 26 00015 0671Q 12-0295
        AM    X4,1,9                                 03152 11 00015 00001 12-0296
        TF    X5,N,11                                03164 26 00019 0671Q 12-0297
        AM    X5,2,9                                 03176 11 00019 00002 12-0298
        C     X1,J,11                                03188 24 00003 0528L 12-0299
        BH    PT27                                   03200 46 03236 01100 12-0300
        BNE   PT28                                   03212 47 03296 01200 12-0301
        SM    J,4                                    03224 12 05283 00004 12-0302
PT27    TF    JMOD,J                                 03236 26 05715 05283 12-0303
        AM    JMOD,2                                 03248 11 05715 00002 12-0304
        TR    JMOD,X1-2,6                            03260 31 0571N 00001 12-0305
        AM    J,20                                   03272 11 05283 00020 12-0306
        B     PT8                                    03284 49 03932 00000 12-0307
PT28    C     X3,J,11                                03296 24 00011 0528L 12-0308
        BH    PT29                                   03308 46 03416 01100 12-0309
        SM    J,8                                    03320 12 05283 00008 12-0310
        C     X3,J,11                                03332 24 00011 0528L 12-0311
        BE    PT30                                   03344 46 03428 01200 12-0312
        TF    JMOD,J                                 03356 26 05715 05283 12-0313
        AM    JMOD,2                                 03368 11 05715 00002 12-0314
```

```
        TR    JMOD,X3-2,6                          03380 31 0571N 00009 12-0315
        AM    J,12                                 03392 11 05283 00012 12-0316
        B     PT8                                  03404 49 03932 00000 12-0317
PT29    SM    J,4                                  03416 12 05283 00004 12-0318
PT30    TF    JMOD,J                               03428 26 05715 05283 12-0319
        AM    JMOD,2                               03440 11 05715 00002 12-0320
        TR    JMOD,X2-2,6                          03452 31 0571N 00005 12-0321
        AM    J,16                                 03464 11 05283 00016 12-0322
        B     PT8                                  03476 49 03932 00000 12-0323
*22 STEP OF FOUR, RIGHT SPAN LONGER                                         0324
PT18    TFM   X1,1,911                             03488 16 00003 0000J 12-0325
        TFM   X2,0,9                               03500 16 00007 00000 12-0326
        TFM   X3,1,9                               03512 16 00011 00001 12-0327
        TFM   X4,2,9                               03524 16 00015 00002 12-0328
        B     PT31                                 03536 49 03596 00000 12-0329
*23 STEP OF FOUR, LEFT SPAN LONGER                                          0330
PT20    TFM   X1,2,911                             03548 16 00003 0000K 12-0331
        TFM   X2,1,911                             03560 16 00007 0000J 12-0332
        TFM   X3,0,9                               03572 16 00011 00000 12-0333
        TFM   X4,1,9                               03584 16 00015 00001 12-0334
PT31    A     X1,N,11                              03596 21 00003 0671Q 12-0335
        A     X2,N,11                              03608 21 00007 0671Q 12-0336
        A     X3,N,11                              03620 21 00011 0671Q 12-0337
        A     X4,N,11                              03632 21 00015 0671Q 12-0338
        C     X1,J,11                              03644 24 00003 0528L 12-0339
        BL    PT32                                 03656 47 03752 01300 12-0340
        BNF   PT33                                 03668 47 03692 01200 12-0341
        SM    J,4                                  03680 12 05283 00004 12-0342
PT33    TF    JMOD,J                               03692 26 05715 05283 12-0343
        AM    JMOD,2                               03704 11 05715 00002 12-0344
        TR    JMOD,X1-2,6                          03716 31 0571N 00001 12-0345
        AM    J,16                                 03728 11 05283 00016 12-0346
        B     PT8                                  03740 49 03932 00000 12-0347
PT32    C     X3,J,11                              03752 24 00011 0528L 12-0348
        BH    PT34                                 03764 46 03872 01100 12-0349
        SM    J,8                                  03776 12 05283 00008 12-0350
        C     X3,J,11                              03788 24 00011 0528L 12-0351
        BE    PT35                                 03800 46 03884 01200 12-0352
        TF    JMOD,J                               03812 26 05715 05283 12-0353
        AM    JMOD,2                               03824 11 05715 00002 12-0354
        TR    JMOD,X3-2,6                          03836 31 0571N 00009 12-0355
        AM    J,8                                  03848 11 05283 00008 12-0356
        B     PT8                                  03860 49 03932 00000 12-0357
PT34    SM    J,4                                  03872 12 05283 00004 12-0358
PT35    TF    JMOD,J                               03884 26 05715 05283 12-0359
        AM    JMOD,2                               03896 11 05715 00002 12-0360
        TR    JMOD,X2-2,6                          03908 31 0571N 00005 12-0361
        AM    J,12                                 03920 11 05283 00012 12-0362
*  CHECK IF TABLE COMPLETE                                                  0363
PT8     TF    JMOD,J                               03932 26 05715 05283 12-0364
        SM    JMOD,4,10                            03944 12 05715 00004 12-0365
        C     JMOD,WFINAL,6                        03956 24 0571N 01359 12-0366
        BNL   SA4                                  03968 46 04028 01300 12-0367
        AM    N,6,10                               03980 11 06718 00006 12-0368
        TF    NMOD,N                               03992 26 06723 06718 12-0369
        SM    NMOD,4                               04004 12 06723 00004 12-0370
        BNF   PT9,NMOD,11                          04016 44 01724 0672L 12-0371
*  TERMINATE FIXED POINT TABLE                                              0372
SA4     AM    J,2,10                               04028 11 05283 00002 12-0373
        TDM   J,0,6                                04040 15 0528L 00000 12-0374
RM3     DC    1,-,*                                04051 Z          04051 01-0375
        BB    ,,,(TEMP1)                           04052 42 00000 00000 12-0376
*                                                                           0377
```

```
*                                                                                 0378
*SUBROUTINE TO ENCODE OUTPUT                                                      0379
*                                                                                 0380
ENCODE CM    Z,0,8                                 04064 14 04407 00000 12-0381
       BNH   PPT3                                  04076 47 04292 01100 12-0382
       CM    Z,1000,8                              04088 14 04407 0J000 12-0383
       BL    *+36                                  04100 47 04136 01300 12-0384
       TFM   CODEAD,CODE8                          04112 16 04135 04347 12-0385
       B     PPT3,CODE0,7,(Q IS CODEAD)            04124 49 04292 04331 12-0386
       MM    Z,8,10                                04136 13 04407 00008 12-0387
PPT4   SM    99,1000                               04148 12 00099 01000 12-0388
       AM    CODEAD,2                              04160 11 04135 00002 12-0389
       CM    99,0,8                                04172 14 00099 00000 12-0390
       BH    PPT4                                  04184 46 04148 01100 12-0391
       AM    RANDAD,1                              04196 11 07280 00001 12-0392
       BNE   PPT1,RANDAD,11                        04208 44 04232 07280 12-0393
       TFM   RANDAD,RANDOM                         04220 16 07280 00704 12-0394
PPT1   TD    PPT1+21,RANDAD,11                     04232 25 04253 07280 12-0395
       AM    99,0                                  04244 11 00099 00000 12-0396
       CM    99,0                                  04256 14 00099 00000 12-0397
       BNL   PPT3                                  04268 46 04292 01300 12-0398
       SM    CODEAD,2                              04280 12 04135 00002 12-0399
PPT3   TF    OUTAD,CODEAD,611                      04292 26 0457N 0413N 12-0400
       AM    OUTAD,2                               04304 11 04575 00002 12-0401
       TFM   CODEAD,CODE0                          04316 16 04135 04331 12-0402
       BB                                          04328 42 00000 00000 12-0403
       DORG  *-9                                   04330                   0404
CODE0  DAC   1,E                                   04330 M5 0       04331 02-0405
CODE1  DAC   1,A                                   04332 M1 0       04333 02-0406
CODE2  DAC   1,-                                   04334 K0 0       04335 02-0407
CODE3  DAC   1,S                                   04336 02 0       04337 02-0408
CODE4  DAC   1,1                                   04338 P1 0       04339 02-0409
CODE5  DAC   1,N                                   04340 N5 0       04341 02-0410
CODE6  DAC   1,D                                   04342 M4 0       04343 02-0411
CODE7  DAC   1,U                                   04344 04 0       04345 02-0412
CODE8  DAC   1,3                                   04346 P3 0       04347 02-0413
*                                                                                 0414
*                                                                                 0415
*SUBROUTINE TO COMPUTE CONTINUOUS Z(W) FROM                                       0416
*       TABLE OF FIXED POINTS (W,Z)                                               0417
*                                                                                 0418
*  CHECK IF ANY FIXED POINTS GIVEN FOR THIS LINE                                  0419
COMP   TF    WP,REF                                04348 26 04419 01531 12-0420
       AM    WP,5,10                               04360 11 04419 00005 12-0421
       BNR   SB1,WP,11                             04372 45 04408 0441R 12-0422
*  EXIT IF W IS IN AREA SUCH THAT Z(W)=0                                          0423
SB2    AM    Z,0,9                                 04384 11 04407 00000 12-0424
       B     EXIT,,6,(Z IN Q)                      04396 49 0579M 00000 12-0425
*  CHECK IF ANY SPANS HAVE BEEN COMPUTED BEFORE                                   0426
SB1    TFM   WPAD,,,         (WP IN Q)             04408 16 04431 00000 12-0427
       SF    WP,,,(WPAD IN Q)                      04420 32 04419 00000 12-0428
       CM    WPAD,0,67                             04432 14 0443J 00000 12-0429
       BNE   SB19                                  04444 47 05104 01200 12-0430
*  CHECK RELATION OF W TO LEFT OF PICTURE                                         0431
       TF    TEMP1,REF                             04456 26 04063 01531 12-0432
       AM    TEMP1,57,10                           04468 11 04063 000N7 12-0433
       C     W,TEMP1,11                            04480 24 04803 0406L 12-0434
       BL    SB2,,,W TO LEFT                       04492 47 04384 01300 12-0435
       BH    SB4,,,W RIGHT OF LEFT EDGE            04504 46 04600 01100 12-0436
*  W AT LEFT EDGE,ENTER FIRST IND. ADDR.                                          0437
SB5    TF    WPAD,TEMP1,6                          04516 26 0443J 04063 12-0438
*  DIRECT EXIT IF W=((WP))                                                        0439
SB3    AM    WPAD,1,610                            04528 11 0443J 00001 12-0440
       TF    ZFIXED-2,WP,11                        04540 25 04585 0441R 12-0441
```

```
         SM    WPAD,1,610                               04552 12 0443J 00001 12-0442
SB11     SF    ZFIXED-2,OUTPUT,7,(OUTAD IN Q)           04564 32 04585 00403 12-0443
         AM    Z,0,,NOTE- Q ADDR. IS ZFIXED             04576 11 04407 00000 12-0444
ZFIXED   DS    ,*                                       04587          00000    0445
         B     EXIT,,6, (ANS IN Q)                      04588 49 0579M 00000 12-0446
*  FIND STARTING SPAN FOR W RIGHT OF LEFT EDGE                                  0447
SB4      AM    TEMP1,4,10                               04600 11 04063 00004 12-0448
         C     W,TEMP1,11                               04612 24 04803 0406L 12-0449
         BL    SB8                                      04624 47 05008 01300 12-0450
         BE    SB5                                      04636 46 04516 01200 12-0451
*  FIRST W TO RIGHT OF 1ST Z INPUT PTS                                          0452
SB6      AM    TEMP1,4,10                               04648 11 04063 00004 12-0453
         C     W,TEMP1,11                               04660 24 04803 0406L 12-0454
         BE    SB5                                      04672 46 04516 01200 12-0455
         BH    SB6                                      04684 46 04648 01100 12-0456
*  ESTABLISH FIXED POINT PRECEDING W                                            0457
         SM    TEMP1,4,10                               04696 12 04063 00004 12-0458
         TF    WPAD,TEMP1,6                             04708 26 0443J 04063 12-0459
*  COMPUTE Z IN SPAN WHERE NO COEFFS KNOWN                                      0460
SB7      AM    WPAD,6,610                               04720 11 0443J 00006 12-0461
         BNR   *+24,WP,11                               04732 45 04756 0441R 12-0462
         B     SB17,,,IF W IN LAST SPAN ON RIGHT        04744 49 05740 00000 12-0463
         SM    WPAD,6,610                               04756 12 0443J 00006 12-0464
SB16     BT    CC,CBC                                   04768 27 05800 06207 12-0465
         BT    CC,CFC,, COMPUTE FRONT COEFFICIENTS      04780 27 05800 05811 12-0466
*  EVALUATE BOTH PARABOLAS, AVERAGE                                             0467
SB15     BTM   EVB,,,             (W IN Q)              04792 17 06760 00000 12-0468
         BTM   EVF,,,             (FS IN Q)             04804 17 06724 00000 12-0469
         TF    TEMP1,W                                  04816 26 04063 04803 12-0470
         S     TEMP1,WP,11                              04828 22 04063 0441R 12-0471
         M     TEMP1,ZF                                 04840 23 04063 05726 12-0472
         TF    TEMP1,99                                 04852 26 04063 00099 12-0473
         TF    TEMP3,WPAD,11                            04864 26 05799 0443J 12-0474
         AM    TEMP3,4,10                               04876 11 05799 00004 12-0475
         TF    TEMP2,TEMP3,11                           04888 26 07083 0579R 12-0476
         S     TEMP2,W                                  04900 22 07083 04803 12-0477
         M     TEMP2,ZB                                 04912 23 07083 05739 12-0478
         A     TEMP1,99                                 04924 21 04063 00099 12-0479
         LD    99,TEMP1                                 04936 28 00099 04063 12-0480
         TF    TEMP2,TEMP3,11                           04948 26 07083 0579R 12-0481
         S     TEMP2,WP,11                              04960 22 07083 0441R 12-0482
         D     97,TEMP2                                 04972 29 00097 07083 12-0483
         A     Z,96                                     04984 21 04407 00096 12-0484
         B     EXIT,,6,(MMOD IN Q)                      04996 49 0579M 00000 12-0485
*  FIRST W IN FIRST SPAN FROM LEFT                                              0486
SB8      SM    TEMP1,4,10                               05008 12 04063 00004 12-0487
         TF    WPAD,TEMP1,6                             05020 26 0443J 04063 12-0488
*  EVALUATE Z IN FIRST SPAN FROM LEFT                                           0489
*  CHECK IF THERE IS NOT JUST ONE SPAN                                          0490
SB9      TF    TEMP1,REF                                05032 26 04063 01531 12-0491
         AM    TEMP1,63,10                              05044 11 04063 00003 12-0492
         BNR   SB10,TEMP1,11                            05056 45 05344 0406L 12-0493
*  IF THERE IS JUST ONE SPAN                                                    0494
         SM    TEMP1,5,10                               05068 12 04063 00005 12-0495
SB13     TD    ZFIXED-2,TEMP1,11                        05080 25 04585 0406L 12-0496
         B     SB11,,,            (Y IN Q)              05092 49 04564 00000 12-0497
*                                                                               0498
*  IF WP HAS BEEN ESTABLISHED PREVIOUSLY                                        0499
SB19     AM    WPAD,2,610                               05104 11 0443J 00002 12-0500
         BNR   *+24,WP,11                               05116 45 05140 0441R 12-0501
         B     SB21,,,IF W PAST PICTURE ON RIGHT        05128 49 05716 00000 12-0502
         AM    WPAD,2,610                               05140 11 0443J 00002 12-0503
         C     W,WP,11                                  05152 24 04803 0441R 12-0504
         BE    SB3,,,             W AT NEXT FIXED POINT 05164 46 04528 01200 12-0505
```

```
*  CHECK IF W PAST FIRST SPAN                                                          0506
        TF    TEMP1,REF                             05176 26 04063 01531 12-0507
        AM    TEMP1,61,10                           05188 11 04063 00001 12-0508
        C     W,TEMP1,11                            05200 24 04803 0406L 12-0509
        BNL   SB12                                  05212 46 05392 01300 12-0510
        AM    WPAD,2,610                            05224 11 0443J 00002 12-0511
        BNR   SB14,WP,11                            05236 45 05284 0441R 12-0512
        SM    TEMP1,3,10                            05248 12 04063 00003 12-0513
        SM    WPAD,6,610                            05260 12 0443J 00006 12-0514
        B     SB13,,,(J)                            05272 49 05080 00000 12-0515
SB14    SM    WPAD,6,610,W IN 1ST SPAN              05284 12 0443J 00006 12-0516
        TF    TEMP2,W                               05296 26 07083 04803 12-0517
        SM    TEMP2,1,10                            05308 12 07083 00001 12-0518
        C     TEMP2,WP,11                           05320 24 07083 0441R 12-0519
        BNE   SB10+12                               05332 47 05356 01200 12-0520
*  EVALUATE FOREWARD PARABOLA IN FIRST SPAN                                            0521
SB10    BT    CC,CFC                                05344 27 05800 05811 12-0522
        BTM   EVF,,,(BS IN Q)                       05356 17 06724 00000 12-0523
        AM    Z,ZF                                  05368 11 04407 05726 12-0524
        B     FXIT,,6,          (MAD IN Q)          05380 49 0579M 00000 12-0525
*  W IS PAST FIRST SPAN, NOT FIXED POINT                                               0526
SB12    TF    NMOD,W,, CHECK IF NEW COEFFICIENTS    05392 26 06723 04803 12-0527
        SM    NMOD,1,10,     NEEDED                 05404 12 06723 00001 12-0528
        SM    WPAD,4,610                            05416 12 0443J 00004 12-0529
        C     WP,NMOD,6                             05428 24 0441R 06723 12-0530
        BL    SB20                                  05440 47 05596 01300 12-0531
        TF    TEMP1,WPAD,11                         05452 26 04063 0443J 12-0532
        SM    TEMP1,4,10                            05464 12 04063 00004 12-0533
        TF    TEMP2,WP,11                           05476 26 07083 0441R 12-0534
        SM    TEMP2,1,10                            05488 12 07083 00001 12-0535
        C     TEMP1,TEMP2,6                         05500 24 0406L 07083 12-0536
        BNL   SB7                                   05512 46 04720 01300 12-0537
        TF    TEMP1,REF,,  PROMOTE FRONT            05524 26 04063 01531 12-0538
        AM    TEMP1,6,10,  COEFFICIENTS TO          05536 11 04063 00006 12-0539
        BNF   SB7,TEMP1,11                          05548 44 04720 0406L 12-0540
        TF    TEMP2,REF,,  BACK COEFFS.             05560 26 07083 01531 12-0541
        AM    TEMP2,30,10                           05572 11 07083 000L0 12-0542
        TR    TEMP1,TEMP2,611                       05584 31 0406L 0708L 12-0543
SB20    BTM   EVB,,10                               05596 17 06760 00000 12-0544
*  CHECK IF W IS IN LAST SPAN                                                          0545
        TF    TEMP1,WPAD,11                         05608 26 04063 0443J 12-0546
        AM    TEMP1,6,10                            05620 11 04063 00006 12-0547
        BNR   *+36,TEMP1,11                         05632 45 05668 0406L 12-0548
        TF    Z,ZB,,IF W WAS IN LAST SPAN           05644 26 04407 05739 12-0549
        B     FXIT,,6                               05656 49 0579M 00000 12-0550
        C     WP,NMOD,6                             05668 24 0441R 06723 12-0551
        BI    SB15+12                               05680 47 04804 01300 12-0552
        BT    CC,CFC                                05692 27 05800 05811 12-0553
        B     SB15+12,,,(JMOD)                      05704 49 04804 00000 12-0554
*  W 1ST PT PAST PICTURE, PROVIDE FOR BYPASS                                           0555
*       OF COMP ROUTINE ON NEXT PASS                                                   0556
SB21    TDM   WPAD,0,6, ZF IN Q-1                   05716 15 0443J 00000 12-0557
RM4     DC    1,-,*                                 05727 Z        05727 01-0558
        B     SB2,,,  ZB IN Q                       05728 49 04384 00000 12-0559
*  FIRST W IS IN LAST SPAN ON RIGHT                                                    0560
SB17    SM    WPAD,6,610                            05740 12 0443J 00006 12-0561
        BT    CC,CBC                                05752 27 05800 06207 12-0562
        BTM   EVB,10                                05764 17 06760 00010 12-0563
        A     Z,ZB                                  05776 21 04407 05739 12-0564
        B     ,,,(EXIT,TEMP3)                       05788 49 00000 00000 12-0565
EXIT    DS    ,*-5                                  05794          00000    0566
*                                                                               0567
```

```
*                                                                                0568
*SUBROUTINE TO COMPUTE COEFFICIENTS OF PARABOLAS                                 0569
*                                                                                0570
CC       SF     *-2,4,,           Q IS CFC          05800 32 05798 00004 12-0571
         TF     JMOD,WPAD,11                        05812 26 05715 0443J 12-0572
         TF     OUT+6,REF                           05824 26 06706 01531 12-0573
         S      JMOD,CC-1                           05836 22 05715 05799 12-0574
         A      OUT+6,CC-3                          05848 21 06706 05797 12-0575
         TF     AL,JMOD,11                          05860 26 00956 0571N 12-0576
         AM     JMOD,1,10                           05872 11 05715 00001 12-0577
         TFM    BL,0,10                             05884 16 00964 00000 12-0578
         TD     BL,JMOD,11                          05896 25 00964 0571N 12-0579
         AM     JMOD,3,10                           05908 11 05715 00003 12-0580
         TF     AM,JMOD,11                          05920 26 00959 0571N 12-0581
         AM     JMOD,1,10                           05932 11 05715 00001 12-0582
         TFM    BM,0,10                             05944 16 00966 00000 12-0583
         TD     BM,JMOD,11                          05956 25 00966 0571N 12-0584
         AM     JMOD,3,10                           05968 11 05715 00003 12-0585
         TF     AN,JMOD,11                          05980 26 00962 0571N 12-0586
         AM     JMOD,1,10                           05992 11 05715 00001 12-0587
         TFM    BN,0,10                             06004 16 00968 00000 12-0588
         TD     BN,JMOD,11                          06016 25 00968 0571N 12-0589
         TF     CL,AN                               06028 26 00971 00962 12-0590
         S      CL,AM                               06040 22 00971 00959 12-0591
         TF     CM,AM                               06052 26 00974 00959 12-0592
         S      CM,AL                               06064 22 00974 00956 12-0593
         TF     CN,AN                               06076 26 00977 00962 12-0594
         S      CN,AL                               06088 22 00977 00956 12-0595
         M      CL,CM                               06100 23 00971 00974 12-0596
         TF     DELTA,99                            06112 26 01025 00099 12-0597
         M      DELTA,CN                            06124 23 01025 00977 12-0598
         SF     93                                  06136 32 00093 00000 12-0599
         TF     DELTA,99                            06148 26 01025 00099 12-0600
         TF     DL,BM                               06160 26 00980 00966 12-0601
         S      DL,BL                               06172 22 00980 00964 12-0602
         M      DL,AN                               06184 23 00980 00962 12-0603
CC1      SF     97,,,Q IS CBC                       06196 32 00097 00000 12-0604
         TF     DL,99                               06208 26 00980 00099 12-0605
         TF     DM,BL                               06220 26 00983 00964 12-0606
         S      DM,BN                               06232 22 00983 00968 12-0607
         M      DM,AM                               06244 23 00983 00959 12-0608
         SF     97                                  06256 32 00097 00000 12-0609
         TF     DM,99                               06268 26 00983 00099 12-0610
         TF     DN,BN                               06280 26 00986 00968 12-0611
         S      DN,BM                               06292 22 00986 00966 12-0612
         M      DN,AL                               06304 23 00986 00956 12-0613
         SF     97                                  06316 32 00097 00000 12-0614
         TF     DN,99                               06328 26 00986 00099 12-0615
         TF     EA,DL                               06340 26 01004 00980 12-0616
         A      EA,DM                               06352 21 01004 00983 12-0617
         A      EA,DN                               06364 21 01004 00986 12-0618
         M      DL,AN                               06376 23 00980 00962 12-0619
         TF     EB,99                               06388 26 01010 00099 12-0620
         M      DM,AM                               06400 23 00983 00959 12-0621
         A      EB,99                               06412 21 01010 00099 12-0622
         M      DN,AL                               06424 23 00986 00956 12-0623
         A      EB,99                               06436 21 01010 00099 12-0624
         M      CM,BN                               06448 23 00974 00968 12-0625
         SF     97                                  06460 32 00097 00000 12-0626
         TF     EC,99                               06472 26 01001 00099 12-0627
         M      EC,AM                               06484 23 01001 00959 12-0628
         TF     EC,99                               06496 26 01001 00099 12-0629
         M      CN,BM                               06508 23 00977 00966 12-0630
         SF     97                                  06520 32 00097 00000 12-0631
```

```
        TF    ET,99                               06532 26 00992 00099 12-0632
        M     ET,AN                               06544 23 00992 00962 12-0633
        S     EC,99                               06556 22 01001 00099 12-0634
        M     EC,AL                               06568 23 01001 00956 12-0635
        TF    EC,99                               06580 26 01001 00099 12-0636
        M     CL,BL                               06592 23 00971 00964 12-0637
        SF    97                                  06604 32 00097 00000 12-0638
        TF    ET,99                               06616 26 00992 00099 12-0639
        M     ET,AN                               06628 23 00992 00962 12-0640
        TF    ET,99                               06640 26 00992 00099 12-0641
        M     ET,AM                               06652 23 00992 00959 12-0642
        A     EC,99                               06664 21 01001 00099 12-0643
        SF    EC-7                                06676 32 00994 00000 12-0644
        TF    ECR,EC                              06688 26 01018 01001 12-0645
OUT     TR    0,FA-2                              06700 31 00000 01002 12-0646
NNMOD   BB    ,,,(N,NMOD)                         06712 42 00000 00000 12-0647
*                                                                         0648
*                                                                         0649
*SUBROUTINE TO EVALUATE PARABOLA AND CLIP                                 0650
*                                                                         0651
*  ENTRY POINT FOR FRONT PARABOLA                                         0652
EVF     TFM   TEMP3,32                            06724 16 05799 00032 12-0653
        TFM   ANS,ZF                             M06736 16 06958 05726 12-0654
        B     JOINT                               06748 49 06784 00000 12-0655
*  ENTRY POINT FOR BACK PARABOLA                                          0656
EVB     TFM   TEMP3,8                             06760 16 05799 00008 12-0657
        TFM   ANS,ZB                             M06772 16 06958 05739 12-0658
JOINT   A     TEMP3,REF                           06784 21 05799 01531 12-0659
        M     TEMP3,W,6                           06796 23 0579R 04803 12-0660
        AM    TEMP3,6,10                          06808 11 05799 00006 12-0661
        TF    TEMP1,TEMP3,11                      06820 26 04063 0579R 12-0662
        S     TEMP1,99                            06832 22 04063 00099 12-0663
        M     TEMP1,W                             06844 23 04063 04803 12-0664
        AM    TEMP3,8,10                          06856 11 05799 00008 12-0665
        A     99,TEMP3,11                         06868 21 00099 0579R 12-0666
        AM    TEMP3,7,10                          06880 11 05799 00007 12-0667
        SF    92                                  06892 32 00092 00000 12-0668
        TF    TEMP2,99                            06904 26 07083 00099 12-0669
        LD    97,TEMP2                            06916 28 00097 07083 12-0670
        D     97,TEMP3,11                         06928 29 00097 0579R 12-0671
        SF    90                                  06940 32 00090 00000 12-0672
        TF    0,92                                06952 26 00000 00092 12-0673
ANS     DS    0,*-5                               06958       00000        0674
*  CLIP OVERSHOOTS                                                        0675
        TF    JMOD,WPAD,11                        06964 26 05715 0443J 12-0676
        AM    JMOD,1,10                           06976 11 05715 00001 12-0677
        TFM   TEMP1,0,8                           06988 16 04063 00000 12-0678
        TF    TEMP1-2,JMOD,11                     07000 26 04061 0571N 12-0679
        SF    TEMP1-2                             07012 32 04061 00000 12-0680
        AM    TEMP1,100,8                         07024 11 04063 00100 12-0681
        C     92,TEMP1                            07036 24 00092 04063 12-0682
        BL    SC2                                 07048 47 07084 01300 12-0683
SC1     TF    ANS,TEMP1,6                        M07060 26 0695Q 04063 12-0684
SC3A    BB    ,,,(TEMP2)                          07072 42 00000 00000 12-0685
SC2     SM    TEMP 1,200,8                        07084 12 04063 00200 12-0686
        C     92,TEMP1                            07096 24 00092 04063 12-0687
        BL    SC1                                 07108 47 07060 01300 12-0688
        BB                                        07120 42 00000 00000 12-0689
                                                                          0690
```

```
*                                                                                  0691
*          F I E L D   D E F I N I T I O N S                                       0692
*                                                                                  0693
        DORG *-9                                   07122                           0694
CARD    DSB  1,80                                  07122                00080      0695
RECMK   DC   1,-                                   07202 Z              07202 01-0696
YINIT   DS   3,M4+11, *          STARRED           01039                00003      0697
YFINAL  DS   3,M6A+11,*    LOCATIONS IN UNUSED     01123                00003      0698
XINIT   DS   3,M6B+11,*  FIELDS OF INSTRUCTIONS    01183                00003      0699
XFINAL  DS   3,M6C+11 *                            01195                00003      0700
NEWNO   DS   3,CARD+2                              07124                00003      0701
MSG     DAC  29,Y= 222 TO 333, X= 444 TO 555-      07204 08 33007 27272 12-0702
                                                   07216 00 63560 07373 12-0703
                                                   07228 73 23006 73300 12-0704
                                                   07240 74 74740 06356 12-0705
                                                   07252 00 75757 50Z   10-0706
                                                                  07205      0707
X       DS   3,M6D+4      *                        01356                00003      0708
WFINAL  DS   3,M6D+7      *                        01359                00003      0709
WINIT   DS   3,SA3+10     *                        01506                00003      0710
ZOFYAD  DS   5,SA3A+6     *                        01526                00005      0711
REF     DS   5,SA3A+11    *                        01531                00005      0712
W       DS   3,SB15+11    *                        04803                00003      0713
YLNAD   DS   5,M6F+11     *                        01147                00005      0714
OUTAD   DS   5,SB11+11    *                        04575                00005      0715
Y       DS   3,SB13+23    *                        05103                00003      0716
CFC     DC   4,3000,CC+11                          05808 L0 00          05811 04-0717
CBC     DC   4,0604,CC1+11                         06204 06 04          06207 04-0718
ENDWHT  DAC  3,20-,,ENDS LINE                      07262 P2 700Z        07263 06-0719
ENDBLK  DAC  4,F20-,,ENDS LINE W/ 10TH LINE MARKER 07268 M5 72700 Z           08-0720
                                                                  07269      0721
OUTPUT  DAS  100,403                               00403                00200      0722
*                                                                                  0723
*  FIELDS FROM SUBROUTINES                                                         0724
TEMP1   DS   10,RM3+12,      *                     04063                00010      0725
TEMP2   DS   10,SC3A+11,     *                     07083                00010      0726
TEMP3   DS   5,EXIT+5,       *                     05799                00005      0727
RANDAD  DSA  RANDOM                                07276 00 704               05-0728
YTABLE  DSB  1,250                                 07281                00250      0729
N       DS   5,NNMOD+6       *                     06718                00005      0730
NMOD    DS   5,NNMOD+11      *                     06723                00005      0731
J       DS   5,SB14-1,   *                         05283                00005      0732
JMOD    DS   5,SB21-1,   *                         05715                00005      0733
DA      DS   2,TEMP2-6   *                         07077                00002      0734
D       DS   2,TEMP2-8   *                         07075                00002      0735
WP      DS   5,SB1+11    *                         04419                00005      0736
WPAD    DS   5,SB1+23    *                         04431                00005      0737
Z       DS   4,SB2+23     *                        04407                00004      0738
ZF      DS   3,SB21+10                             05726                00003      0739
ZB      DS   3,SB21+23                             05739                00003      0740
ANS     DS   4,ZFIXED+12 *                         04599                00004      0741
CODEAD  DS   5,PPT4-13,*                           04135                00005      0742
M       DSB  4,5,4                                 00004                00005      0743
X1      DS   ,M-1                                  00003                00000      0744
X2      DS   ,M+3                                  00007                00000      0745
X3      DS   ,M+7                                  00011                00000      0746
X4      DS   ,M+11                                 00015                00000      0747
X5      DS   ,M+15                                 00019                00000      0748
CLRM    DC   21,0-                                 07531 00 00000 00000 12-0749
                                                   07543 00 00000 0Z    09-0750
                                                                  07551      0751
AAA     DC   2,0,CLRM-1                            07549 00             07550 02-0752
BBB     DC   2,0,CLRM-5                            07545 00             07546 02-0753
CCC     DC   2,0,CLRM-9                            07541 00             07542 02-0754
```

```
DDD     DC    2,0,CLRM-13                                     07537 00        07538 02-0755
EEE     DC    2,0,CLRM-17                                     07533 00        07534 02-0756
MMOD    DS    5,SB8-1    *                                    05007           00005    0757
MAD     DS    5,PT12-1,   *                                   02071           00005    0758
FS      DS    4,SB10+11   *                                   05355           00004    0759
BS      DS    4,SB10+23   *                                   05367           00004    0760
BLOCK   DS    1                                               07552           00001    0761
        DORG  ORIG+10                                         00954                    0762
AL      DS    3                                               00956           00003    0763
AM      DS    3                                               00959           00003    0764
AN      DS    3                                               00962           00003    0765
BL      DS    2                                               00964           00002    0766
BM      DS    2                                               00966           00002    0767
BN      DS    2                                               00968           00002    0768
CL      DS    3                                               00971           00003    0769
CM      DS    3                                               00974           00003    0770
CN      DS    3                                               00977           00003    0771
DL      DS    3                                               00980           00003    0772
DM      DS    3                                               00983           00003    0773
DN      DS    3                                               00986           00003    0774
ET      DS    6                                               00992           00006    0775
FC      DS    9                                               01001           00009    0776
EA      DS    3                                               01004           00003    0777
EB      DS    6                                               01010           00006    0778
ECR     DS    8                                               01018           00008    0779
DELTA   DS    7                                               01025           00007    0780
ABC     DC    1,-                                             01026 Z         01026 01-0781
        DEND  START                                           00404                    0782
L60010000500J50040000000ZL60000000500M90003600000       00192 M6 00220 01200 J2007Q3
00000000000010203040002040608000306090210040802161005001510200602181420070400784
52035304540363248445532494653604842 L60017500500L10025000000L60002000500    00785
11282008061422300908172630000000000050607080900121416181518112427202428223630078 6
654627544536271 8Z L10028400020J50030000000M900404000M90003800000              00787
```